Final Report

Brisbane Water Estuary Catchments Overland Flood Study

59918113

Prepared for
Central Coast Council

28 May 2021

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Our report is based on information made available by the client. The validity and comprehensiveness of supplied information has not been independently verified and, for the purposes of this report, it is assumed that the information provided to Cardno is both complete and accurate. Whilst, to the best of our knowledge, the information contained in this report is accurate at the date of issue, changes may occur to the site conditions, the site context or the applicable planning framework. This report should not be used after any such changes without consulting the provider of the report or a suitably qualified person.

Foreword

NSW Government Flood Prone Land Policy is directed towards providing solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain modification measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee -

   Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.

2. Data Collection -

   The collection of data such as historical flood levels, rainfall records, land use, soil types etc.

3. Flood Study -

   Determines the nature and extent of the flood problem.

4. Floodplain Risk Management Study –

   Evaluates floodplain management measures for the floodplain in respect of both existing and proposed development.

5. Floodplain Risk Management Plan –

   Involves formal adoption by Council of a management plan for the floodplain.

6. Implementation of the Plan –

   Implementation of actions to manage flood risks for existing and new development.

This Flood Study has been prepared for Central Coast Council by Cardno addressing Parts 2 and 3 of the Floodplain Management process. The aim of the study is to identify the existing flood behaviour for a range of flood events to allow Council to asses and plan for current and future flood risks.

Executive Summary

Introduction

Cardno were commissioned by Central Coast Council to undertake a Overland Flood Study for four catchments flowing into the Brisbane Water estuary.

This study has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damages and risks due to severe events such as storm surge and climate change.

Catchment Description

The study is focused on the Brisbane Water Estuary and four catchments within the Central Coast Council Local Government Area (LGA). The Study Area lies on either side of the estuary. On the west, it extends from Woy Woy Bay to West Gosford while on the east, it encompasses the Green Point catchment.

Historical flooding events show that flooding occurs due to a combination of overland rainfall and storm surge tidal events within the catchment.

The Brisbane Water Foreshore Flood Study was completed by Cardno Lawson Treloar in 2013. The flood study looked at primarily the mainstream inundation within the estuary. Other studies in the catchment relied on a combination of 1d hydraulics or hydrology models.

There are potential flood risks to residents within the catchment due to the various sources of inundation including concerns about impacts of climate change and future development. Consultation with the community and stakeholders was undertaken at several stages of the study in order to understand historical issues with flooding. This study supersedes all previous flood modelling within the overland zones and provides updated flood mapping.

Existing Flooding Behaviour

The existing flooding behaviour within the Brisbane Water Estuary catchment and its surrounding catchments occurs over short durations and flows downstream along steep catchments. Flow paths are generally confined until they reach the low-lying areas which contain the highest density of housing and commercial lots. Sensitivity analysis was undertaken to understand the impacts that houses and fences in these areas have on the flow path. It identified that they disrupt the flow paths. Flood extents in these areas are wider and shallower flood depths are observed.

Flows in urbanised areas are primarily carried along roads and established drainage corridors. Along the western catchments, the railway embankment forms a major hydraulic control for several overland flow paths. The Tascott catchment in particular has been identified as an area of concern with regards to flooding.

Along the eastern Green Point catchment, flooding has been identified along Avoca Road and Davistown Roads. Flooding has also been investigated with regards to joint probability modelling and assessing their impacts on waterfront properties.

Key Outcomes

This study has quantified the flood behaviour in the Brisbane Water Estuary catchment, and the flood models that have been developed as part of this study will assist Central Coast Council to undertake future planning assessments, emergency response review and floodplain risk management measures under the Floodplain Risk Management Study and Plan stages. A range of preliminary options were considered to reduce the flood risk including flood levees, emergency response and land use planning. The recommendation based on this preliminary assessment is that it may not be practical to eliminate all flood risks from the study area based on current catchment conditions. Instead, the focus needs to be on flood related planning for future development and reduce risk by increasing flood awareness in the catchment.

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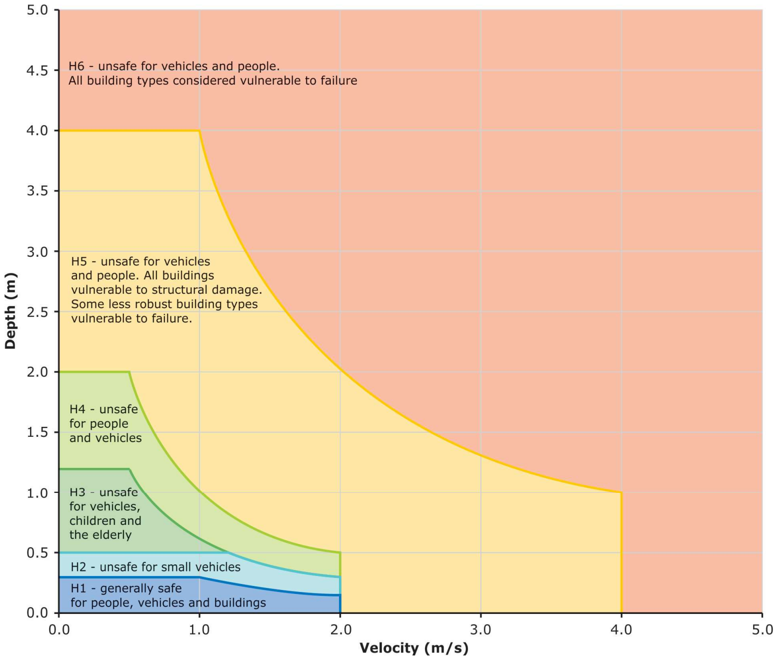
Glossary of Terms

<table>
<tr><td>Australian Height Datum (AHD)</td><td>A standard national surface level datum approximately corresponding to mean sea level.</td></tr>
<tr><td>Average Recurrence Interval (ARI)</td><td>The long-term average period between occurrences equalling or exceeding a given value. For example, a 20 year ARI flood would occur on average once every 20 years.</td></tr>
<tr><td>Annual Exceedance Probability (AEP)</td><td>The probability of an event occurring or being exceeded within a year. For example, a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided.
<table>
<tr><th>AEP</th><th>ARI</th></tr>
<tr><td>63.2 %</td><td>1 year</td></tr>
<tr><td>39.3 %</td><td>2 year</td></tr>
<tr><td>18.1 %</td><td>5 year</td></tr>
<tr><td>10 %</td><td>10 year</td></tr>
<tr><td>5 %</td><td>20 year</td></tr>
<tr><td>2 %</td><td>50 year</td></tr>
<tr><td>1 %</td><td>100 year</td></tr>
<tr><td>0.5 %</td><td>200 year</td></tr>
<tr><td>0.2 %</td><td>500 year</td></tr>
</table></td></tr>
<tr><td>Cadastre, cadastral base</td><td>Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.</td></tr>
<tr><td>Catchment</td><td>The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.</td></tr>
<tr><td>Defined Flood Event (DFE)</td><td>A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1% AEP flood event.</td></tr>
<tr><td>Development</td><td>The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.</td></tr>
<tr><td>Discharge</td><td>The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.</td></tr>
<tr><td>Flash flooding</td><td>Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.</td></tr>
<tr><td>Flood</td><td>Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences.</td></tr>
<tr><td>Flood control lot</td><td>A lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).</td></tr>
<tr><td>Flood fringe</td><td>The remaining area of flood-prone land after floodway and flood storage areas have been defined.</td></tr>
<tr><td>Flood hazard</td><td>Potential risk to life and limb caused by flooding.</td></tr>
</table>

Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood Planning Constraints Categorization (FPCC)	The FPCC can be derived from flood studies under the floodplain- specific management process outline in the Australian Disaster Resilience Handbook 7 provides guidance. FPCCs can be readily used to identify planning constraints for different land use activities on a single map or set of maps. The severity constraints are identified based on four (4) different FPCCs Categories. These go from the areas with the most severe constraints, FPCC1, to FPCC4 with the least constraints.
Flood planning levels (FPLs)	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the “Standard flood event” of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.

Hazard H1 – H6	Guidance from the Technical Flood Risk Management Guideline (Australian Emergency Management Institute, 2014) classifies hazard into six categories from H1 (least hazard) to H6 (highest hazard). Book 6, Chapter 7 of the ARR 2019 guidelines support the use of these curves for risk management. The general hazard curves are shown in the figure below. 
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings. (Floodplain Development Manual, 2005).
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety (Floodplain Development Manual, 2005).
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Minimum Floor Level	The minimum floor level is the level (AHD) of the habitable floor defined by the Flood Planning Level as determined in the applicable flood study or floodplain risk management plan.
Overland Flow	The term overland flow is used interchangeably in this report with “flooding”.
Peak discharge	The maximum discharge occurring during a flood event.

Probable maximum flood (PMF)	The largest flood that could occur at a particular location, usually estimated from Probably Maximum Precipitation (PMP). The PMF define the extent of flood- prone land- that is floodplain.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a more detailed explanation see AEP and Average Recurrence Interval.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

1 Introduction

Cardno (NSW/ACT) Pty Ltd was commissioned by Central Coast Council (Council) to undertake an overland flood study for the four catchments of Coorumbine Creek (C17), Point Clare to Koolewong (**C18**), Woy Woy Bay (**C19/T, C19/U, C19/V & C19/W**) and Green Point (**C8**).

The assessment this report looks at flooding associated with catchment rainfall flowing to a creek, open channel or open canal and the capacity of the channel is generally exceeded and areas where catchment rainfall cannot enter the stormwater drainage system and flows 'overland', which can be through properties or down streets.

The aim of the study is to inform the basis for a subsequent floodplain risk management study for the detailed assessment of flood mitigation options and management measures.

1.1 Study Process

The primary tasks of this flood study comprise four main stages, with community consultation undertaken throughout:

- Compilation and review of available data for the study area;
- Establishment of a hydrologic and hydraulic computer model for the study area;
- Calibration and validation of the models;
- Determination of flood depths, velocities and extents for a range of design storms.

These models can also be used for future studies to investigate various management and flood mitigation options for the existing catchment conditions and will assist in evaluating long term flood management strategies to address existing flood risks have been defined in this study.

1.2 Study Objectives

The objectives of the study are to:

- Investigate mainstream and local overland flooding regimes including the capacity of the existing trunk drainage.
- Determine catchment-wide flood levels, extents, velocities and flows for a range of design events including consideration of climate change projections.
- Identify provisional hydraulic and hazard categories for a range of design events.
- Determine flood emergency response classification of communities.
- Determine an appropriate flood planning area including sensitivity to climate change.
- Consider the sensitivity of flood behaviour to changes in flood producing rainfall events due to climate change and blockages at critical infrastructure, including the effects of future mitigation measures to address storm surge.
- Involve the local community to gather historical flood information and/or records.
- Develop information to assist in future floodplain management activities including management of the overland flooding.

1.3 Study Area

The study area covers four catchments of the Brisbane Water estuary including:

- Coorumbine Creek (**C17**)
- Point Clare to Koolewong (**C18**)
- Woy Woy Bay (**C19/T, C19/U, C19/V & C19/W**)
- Green Point (**C8**)

Coorumbine Creek, Point Clare to Koolewong and Woy Woy Bay drain to the east into Brisbane Water Estuary. Green Point catchment drains to the west into Brisbane Water Estuary. Each catchment contributes stormwater flows overland via a combination of small streams and drainage networks into the Brisbane Water Estuary which is dominated by fluctuating tides.

Coorumbine Creek catchment occupies a total area of 3.9 km^2 and includes industrial areas of West Gosford and mid- to high-density residential areas. The major roads within the catchment are Central Coast Highway and Brisbane Water Drive.

Point Clare to Koolewong catchment occupies a total area of 6.9 km^2 and includes mainly thick vegetation to the west and residential areas to the lower eastern side. The railway line also traverses along the eastern boundary of the catchment. The major road within the catchment is Brisbane Water Drive.

Woy Woy Bay catchment is the largest catchment within the study area and occupies a total area of 14.4 km^2. Over 90% of the catchment is covered with dense vegetation but residential properties along the eastern part of the catchment. The major road within the catchment is Woy Woy Road.

Green Point catchment occupies a total area of 9.0 km^2 and includes residential areas and thick vegetation to a similar proportion to the Woy Woy Bay catchment. The major roads within the catchment are Avoca Drive and Davistown Road.

The boundaries of each catchment are plotted in **Figure 1-1**.

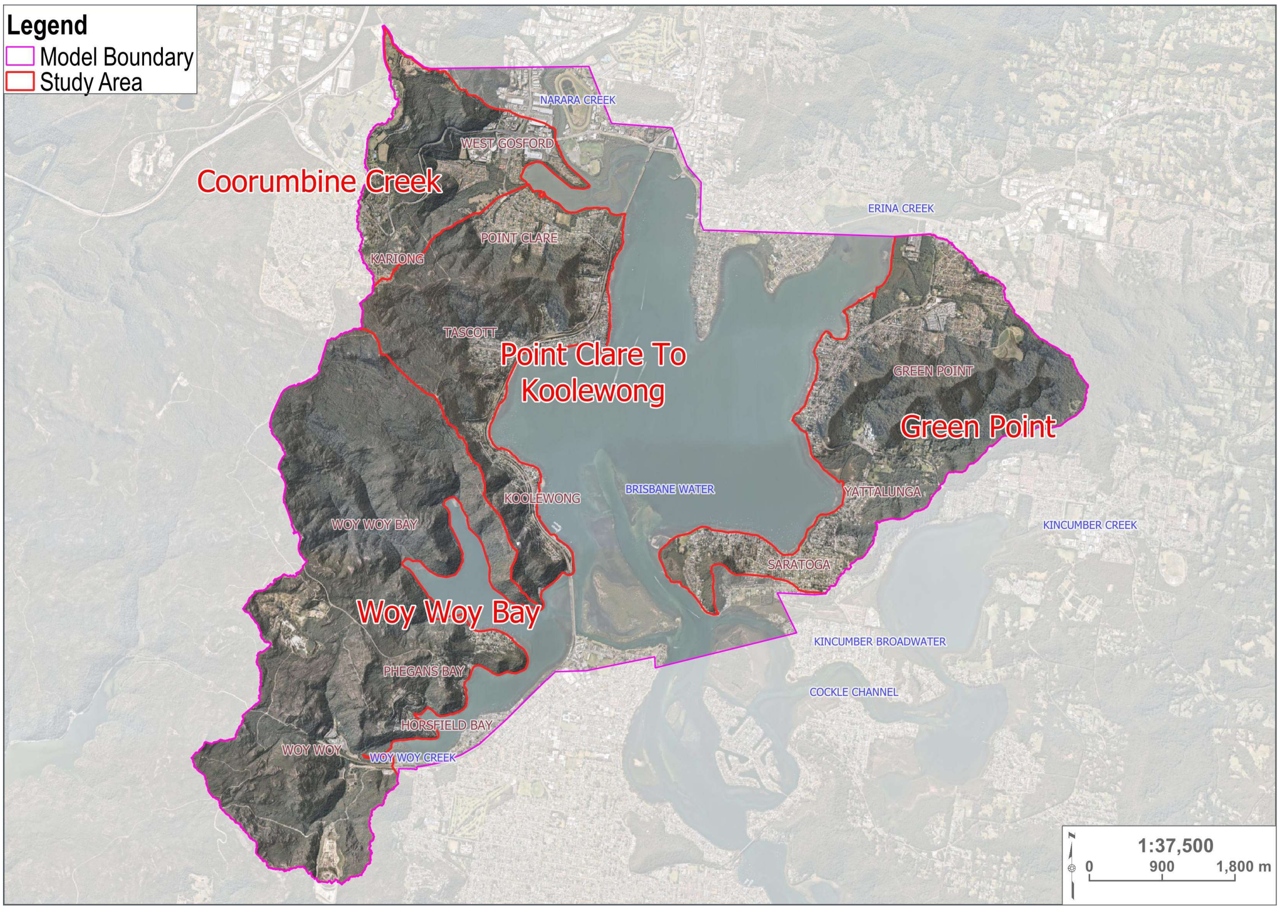


Figure 1-1 Study Area Catchments

2 Available Data

Data adopted for this Study has been collated from a number of sources for application to the flood models and overall assessment.

2.1 Previous Studies

Previous studies undertaken within the four catchments include:

2.1.1 Brisbane Water Foreshore Flood Study, Cardno Lawson Treloar, May 2009

This report describes the development of flood planning level (FPL) parameters for the Brisbane Water Foreshore based on extensive data analysis and calibrated modelling systems. Hydraulic modelling of the design catchment storm events was undertaken using the calibrated Delft3D modelling system.

Downstream boundary water levels, bathymetric data, the 1% Probability of Exceedance (PoE) levels, were determined for use in individual creek flooding studies. The 1% PoE levels represents the level that has a 99% chance that it will not be exceeded during any creek flood event.

2.1.2 Brisbane Water Foreshore Floodplain Risk Management Study and Plan, Cardno 2015

This Study evaluated the flood risk across the Brisbane Water floodplain and identified, assessed and compared various management options to address the risk. This study primarily considered those risks associated with coastal flooding of the foreshore of Brisbane Water and does not incorporate catchment flooding from the tributaries of Brisbane Water (such as Narara and Erina Creeks). These tributary floodplains have been addressed in separate floodplain risk management documents held by Council.

The Study estimated the Average Annual Damage of flooding to be $5,448,989 for the 1% AEP design event without sea level rise. The study recommended the FPL for the Brisbane Water foreshore floodplain as 1% AEP design flood levels with sea level rise (as defined in Council’s policy) + 0.5 m Freeboard. Furthermore, it was recommended that vulnerable or longer-term development types such as critical infrastructure consider the application of the 2100 projected sea level rise as part of the FPL.

The Brisbane Water FRMP has been developed to direct and co-ordinate the future management of flood prone land around the Brisbane Water Foreshore. It also aims to educate the community about flood risks so that they can make more informed decisions regarding their individual exposure and responses.

2.1.3 Koolewong Drainage Study, Ivan Tye and Associates, September 2001

This study was undertaken to carry out a drainage investigation and to develop a drainage strategy for the Koolewong area. It evaluated the existing drainage system, determined options to improve the existing drainage system and to manage redevelopment in the area and also provided a drainage management plan for the area.

2.1.4 Point Clare Trunk Drainage Study, Management Study and Plan, Webb McKeown and Associates Pty Ltd, 1994

This study was undertaken to develop a combination of mitigation options which would provide 100 year ARI (1% AEP) flood protection for the houses and reduce the frequency of flooding of the properties to a level acceptable to Council and the community of Point Clare.

In order to define the drainage requirements necessary to achieve these objectives, a hydrologic/hydraulic model was established for the study area. The model was used to assess the existing drainage system behaviour, determine the design 10%, 5%, 2% and 1% AEP floods and quantify the relative effects of alternative flood mitigation measures.

The study determined that the then existing pipe drainage system had capacities ranging from less than 10% up to 1% AEP in different parts of the system.

2.1.5 Sun Valley Trunk Drainage Strategy, Kinhill Engineers Pty Ltd, 1991

This study was undertaken to investigate the then existing stormwater drainage system and to check the capacities to cope with the proposed development as part of the Erina-Green Point-Terrigal Urban Release Area. Peak flows were determined using XPRAFTS and peak flood levels were estimated using HEC-2. These models were calibrated to the February 1990 event.

It was predicted that no houses were flooded by the 1% AEP flood event under fully developed catchments conditions. Option 2, which involved only minor works to upgrade surface drainage on the low-lying valley floor, was recommended with total cost of $21,000.

2.2 GIS Data

Council provided Geographic Information System (GIS) data for preparing this Overland Flood Study model and reporting including:

- Cadastral boundaries
- Land use zones
- LiDAR gridded data
- Stormwater drainage network (pit and pipe)

2.2.1 LiDAR Topographic Survey

Council provided 1m gridded LiDAR (aerial survey) data over the entire study area which was collected in 2013.This LiDAR data forms the basis for the Digital Elevation Model (DEM) used in this study. Most of the urban areas in the study area are low-lying and between 1.5m AHD to 25m AHD. A high proportion of properties and major roads lie up to 5m AHD to 10m AHD in the catchment.

2.2.2 Stormwater Network

Review of Council's existing pit and pipe data indicated approximately 3060 pipes and 3270 pits in the overall study area.

Table 2-1 to **Table 2-3** summarise the available existing drainage network data for the study area.

Table 2-1 Data Availability for Existing Drainage Pits

Parameters	Available Data
Pit Type	89%
Lid Type	85%
Pit Length	72%
Lid Length	7%
Lid Width	7%
Grate Length	36%
Grate Width	36%
Surface AHD level	4%
Opening Length	37%
Pit Width	41%
Pit Depth	42%

Table 2-2 Data Availability for Existing Drainage Pipes

Parameters	Available Data
Invert US	40%
Invert DS	38%
Pipe Length	90%
Material	91%
Diameter	91%

Table 2-3 Data Availability for Existing Drainage Headwalls / Pipe Outlets

Parameters	Available Data
Type	100%
Surface AHD Level	3%
Construction Material	100%
Upstream Connecting Pipe Data	100%
Depth	47%
Width	39%

During the model setup phase, the best approach was applied for each area/network based on the level of information available to simulate pit inlet capacity. A combination of site visits, desktop assessment and terrain data was used to supplement the missing data. Details on the stormwater network methodology are described in **Section 5.2.4.**

2.3 West Gosford Intersection Upgrade

Roads and Maritime Services (RMS) modified the intersection of Central Coast Highway and Brisbane Water Drive at West Gosford in 2015. The pit and pipe data provided by Council did not include details of the new upgraded drainage network. Information for the upgraded drainage network was extracted from the DRAINS model created for this intersection and used to update the pit and pipe information for the flood study.

2.4 Works as Executed Drawings

Council provided various works-as-executed (WAE) drawings for various parts of the study area. Some of these were used to validate the Council’s drainage GIS data and make adjustments where applicable.

2.5 Site Inspections

Detailed site inspections were undertaken in all four catchments on 07/03/2018, 14/03/2018 and 16/03/2018. They provided the opportunity to fine tune the modelling approach to capture various drainage features and to visually identify potential flooding hotspots in the catchments.

Selected photos of culverts and the estuary embankment from the site inspection are shown in **Figure 2-1.**

2.6 Detail Survey

For the majority of waterways and structures, there was sufficient information available from the LIDAR data, or previous survey and WAE drawings to represent the overland flow conditions. Two locations were identified as requiring additional survey due to lack of data:

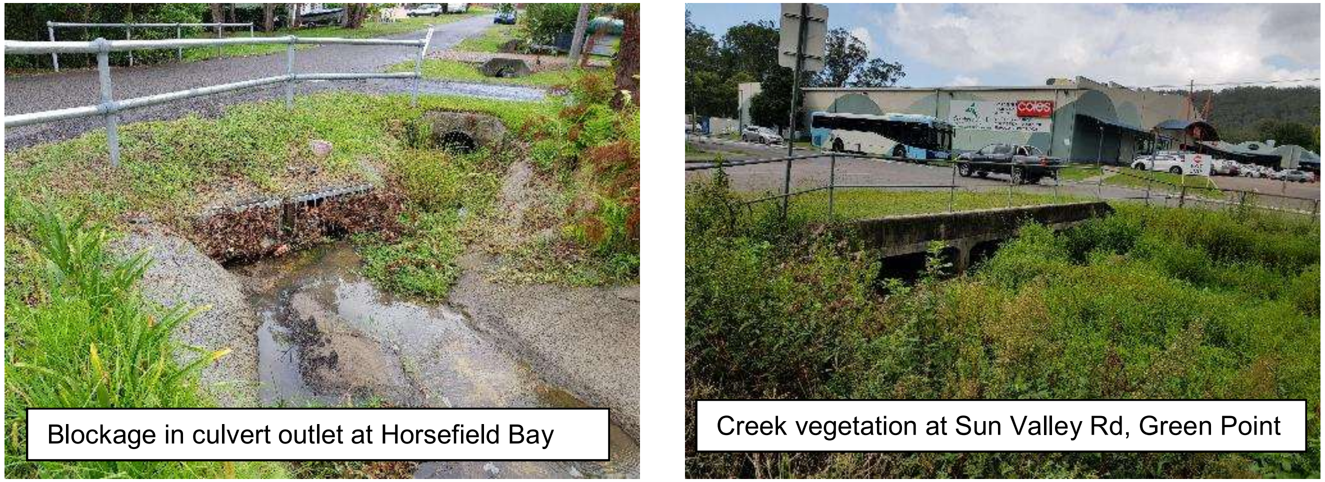
- Sun Valley Road, Green Point: Survey of the existing channel and the associated hydraulic structures.
- Railway corridor, Woy Woy to West Gosford: Survey of major culverts under the railway line.

The detail survey data is provided in **Appendix A**.

Culverts under Bluefish Crescent, Tascott

Crossing under Brisbane Water Drive, Point Clare

Submerged outlet, Brisbane Water, Tascott



Blockage in culvert outlet at Horsefield Bay

Creek vegetation at Sun Valley Rd, Green Point

Figure 2-1 Site Visit Photos

3 Rainfall Analysis

Rainfall Intensity-Frequency-Duration (IFD) data at the Narara gauge was compared for ARR 1987 and ARR 2016 as well as an at-site rainfall frequency analysis. All IFD values were obtained from the Bureau of Meteorology (BOM) for the Narara gauge (shown in **Figure 6-1**).

3.1 ARR 1987 IFD

Recurrence values for ARR 1987 are calculated based on an Average Recurrence Interval (ARI) but updated guidelines from ARR 2016 data report the storm frequencies based on an Annual Exceedance Probability (AEP). The ARR 1987 storm burst depths were adjusted from ARI to AEP for comparison with the ARR 2016 storm burst depths and are tabulated in **Table 3-1**.

Table 3-1 ARR 1987 Storm Burst Depths (adjusted to AEP)

Duration (mins)	Number of Exceedances per Year	Storm Burst Depth (mm)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
15	14.8	17.3	22.4	26.3	30.3	34.9	38.6
30	21.5	25.1	32.6	38.3	44.2	51.0	56.5
45	25.5	29.8	38.8	45.7	52.7	61.1	67.7
60	29.4	34.4	45.0	53.1	61.2	71.2	78.8
90	34.3	40.2	52.9	62.5	72.2	84.3	93.4
120	39.2	45.9	60.7	72.0	83.2	97.4	108.0
180	46.2	54.1	72.1	85.7	99.3	116.4	129.3
360	60.6	71.2	96.3	115.2	134.4	157.8	176.4

3.2 ARR 2016 IFD

ARR 2016 guidelines provide more data and guidance to estimate flood behaviour as it is based on a more extensive database and accurate statistics. The 2016 IFD data, which replaces both the ARR 1987 IFDs and the interim 2013 IFDs, provides better estimates of the 2% and 1% AEP storms. ARR 2016 Data is obtained from the ARR Data Hub and is attached as **Appendix B**. BOM has undertaken an extensive analysis of available gauges and it would be expected that storm burst depths in the region recommended by ARR 2016 would be based on the analysis of multiple gauges.

Design storm burst depths from BOM are summarised in **Table 3-2**.

Table 3-2 ARR 2016 Storm Burst Depths

Duration (mins)	Number of Exceedances per Year	Storm Burst Depth (mm)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
15	14.7	16.9	24.2	29.8	35.7	44.3	51.6
30	20.2	23.2	33.5	41.3	49.6	61.7	71.9
45	*23.3*	*26.8*	*38.8*	*47.8*	*57.5*	*71.5*	*83.2*
60	26.4	30.4	44.0	54.3	65.3	81.2	94.5
90	30.7	35.3	51.0	62.9	75.6	93.8	109.0
120	34.2	39.3	56.6	69.7	83.6	104.0	121.0
180	40.0	45.8	65.7	80.6	96.5	119.0	139.0
360	53.4	60.8	85.9	105.0	125.0	153.0	177.0

3.3 Narara Rainfall Gauge IFD

Long-term pluviograph rainfall data recorded at the Narara rainfall gauge was obtained from Manly Hydraulics Laboratory (MHL) and has been used for an at-site gauge rainfall frequency analysis. The gauge details are summarised in **Table 3-3**.

Table 3-3 Narara Gauge Station Details

Site	Station ID	Data period	Number of years	Gauge Type	Source
Narara	561085	1989 - 2018	30	Pluviograph (6 min intervals)	MHL

Annual maximum storm burst depths were extracted from the recorded 30 years of data for 10 storm burst durations: 30 mins, 60 mins, 90 mins, 2 hr, 3 hr, 6 hr, 9 hr, 12 hr, 18 hr and 24 hr. The annual maximum storm burst depths for each duration are summarized in **Appendix B**. Analysis of the annual maximum burst depths was undertaken using TUFLOW FLIKE which has been developed to undertake flood frequency analysis. FLIKE is a comprehensive Bayesian analysis tool that fits a probability model to gauged and censored historic data. Model output includes probability plots showing data, quantiles and confidence limits based on a fitted Log Pearson Type III probability model.

The frequency analysis was then compared to the storm burst depths of ARR 2016 and ARR 1987. Results are presented in probability plots for each of the 10 analysed rainfall durations and are shown in **Appendix B**. Each plot shows the fit as well as the quantile values and confidence limits. Within the plot window the y-axis shows rainfall depth (log rainfall) and the x-axis displays the Annual Exceedance Probability (AEP) in terms of 1 in Y years.

Narara storm burst depths for 1 Exceedances per Year (EY) bursts were interpolated from the frequency analysis of 1 in 1.5 AEP (1.1 EY), 1 in 5 and 1 in 2 burst depths. The 15 minute and 45 minute Narara storm burst depths were extrapolated from the 30 min, 60 min, 90 min, 120 min and 180 min storm burst. Storm burst depths obtained for the Narara gauge are summarised in **Table 3-4**.

Table 3-4 Narara Gauge Storm Burst Depths

Duration (mins)	Number of Exceedances per Year	Storm Burst Depth (mm)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
15	20.1	23.3	31.4	34.8	36.9	38.4	38.8
30	25.3	29.1	39.7	45.3	49.7	54.5	57.4
45	29.3	34.0	48.4	57.0	64.5	73.6	79.8
60	32.4	38.0	56.2	68.2	79.5	93.9	104.6
90	37.9	44.3	65.4	79.7	93.7	112.1	126.1
120	41.2	48.1	72.5	91.0	110.5	138.4	161.4
180	46.6	53.7	79.6	100.0	122.3	155.4	183.9
360	58.8	66.6	95.0	116.8	140.2	174.4	203.3

3.4 IFD Comparison

Percentage differences between the three sets of data were compared to identify the most accurate set of parameters to be used for this Study. The three sets of data have been plotted in **Figure 3-1.** ARR 1987 and ARR 2016 storm burst depths were compared as summarised in **Table 3-5**.

Table 3-5 Storm Burst Depth Difference - ARR 2016 Less ARR 1987

Duration (mins)	Difference (%) Exceedances per Year	Difference (%)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
15	-1%	-3%	8%	13%	18%	27%	34%
30	-6%	-8%	3%	8%	12%	21%	27%
45	-8%	-10%	0%	5%	9%	17%	23%
60	-10%	-12%	-2%	2%	7%	14%	20%
90	-10%	-12%	-4%	1%	5%	11%	17%
120	-13%	-14%	-7%	-3%	0%	7%	12%
180	-13%	-15%	-9%	-6%	-3%	2%	8%
360	-12%	-15%	-11%	-9%	-7%	-3%	0%

From **Table 3-5**:

1. The storm burst depths for frequent events (eg 50% and 20% AEPs) are lower than the ARR 1987 storm burst depths.
2. For short durations less than 1 hour, the trend is for the storm burst depth from ARR 2016 to increase compared to ARR1987 as storm severity increases (i.e. as AEP decreases). For durations greater than 3 hours, the trend is for the storm burst depth from ARR 2016 to be lower in comparison to ARR 1987 storm burst depths for all AEPs.
3. For storm burst durations of typical interest in small urban or urbanising catchments, namely 1 hour to 3 hours, the trend is for the storm burst depth of ARR 2016 compared to ARR 1987 to range from 12-15% lower in frequent events to up to 20% greater 1% AEP storm bursts.

Storm burst depths of ARR2016 and the Narara gauge were compared as summarised in **Table 3-6**.

Table 3-6 Storm Burst Depth Difference - Narara Gauge Less ARR 2016

Duration (mins)	Difference (%) Exceedances per Year	Difference (%)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
15	37%	38%	30%	17%	3%	-13%	-25%
30	25%	25%	19%	10%	0%	-12%	-20%
45	26%	27%	25%	19%	12%	3%	-4%
60	23%	25%	28%	26%	22%	16%	11%
90	24%	25%	28%	27%	24%	19%	16%
120	20%	22%	28%	31%	32%	33%	33%
180	17%	17%	21%	24%	27%	31%	32%
360	10%	10%	11%	11%	12%	14%	15%

Table 3-6 shows that all Narara storm burst depths for frequent events are greater than the ARR 2016 except for the 2% AEP 15 min, 2% AEP 30 min, 1% AEP 15 min, 1% AEP 30 min and 1% AEP 45 min storm burst depths. For these four storm bursts, the Narara storm burst are lower than ARR 2016 and comparable to ARR 1987 storm burst depths.

3.5 Recommended IFD

Considering that the differences in the storm burst depths for durations of typical interest in small urban catchments (namely 1 hour to 3 hours) at the Narara gauge is such that these storm burst depths should be adopted for analysis purposes notwithstanding that the storm burst durations for several short durations are lower than ARR 2016.The adoption of the Narara IFD provides a conservative and site specific estimation of flood behaviour. It is recommended that the Narara design storm burst depths given in **Table 3-4** be adopted for assessment purposes.

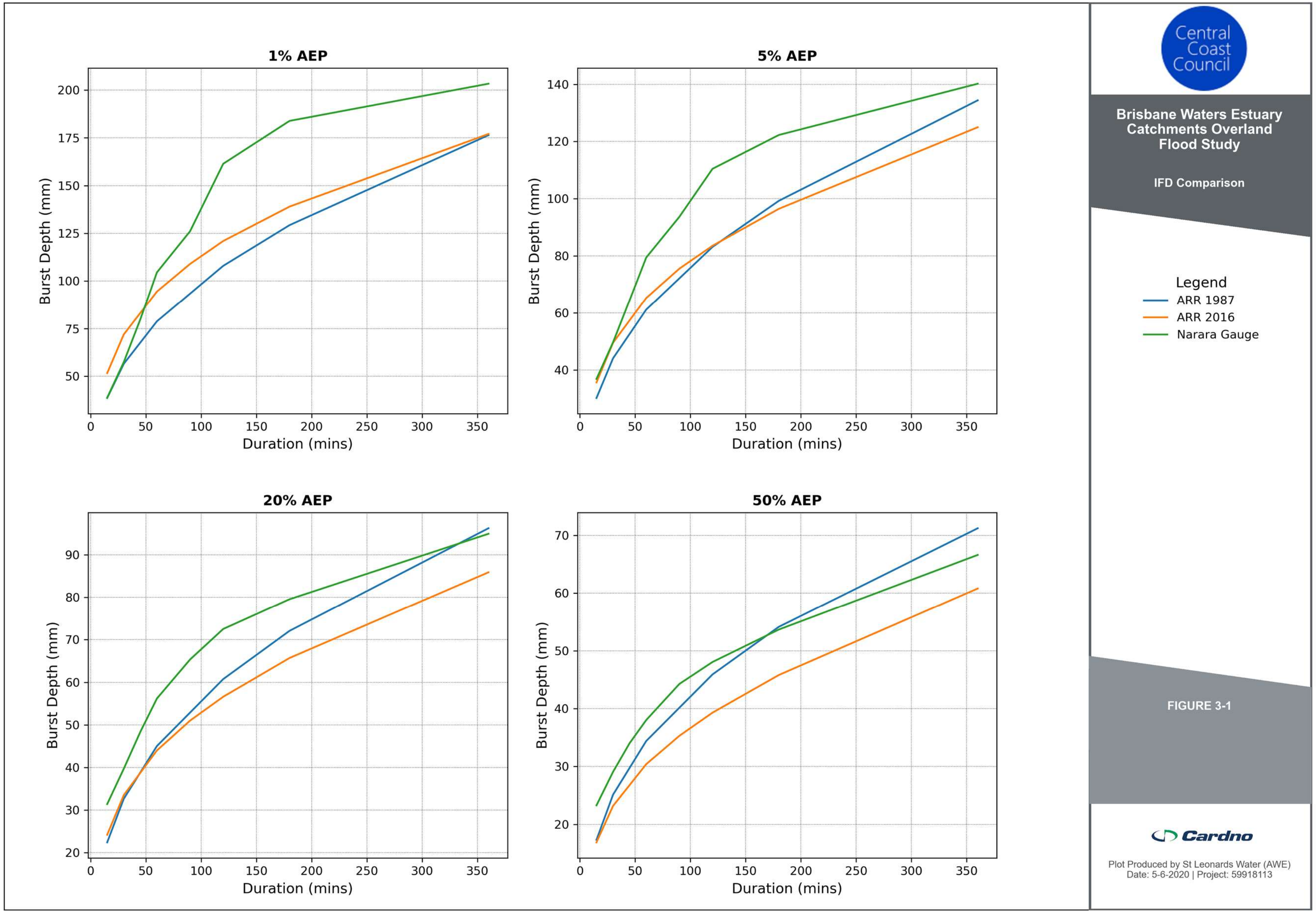


Figure 3-1 IFD Comparison

4 Community Consultation

Community involvement is essential to the success of the overall floodplain risk management process. It enables the community to contribute local knowledge of flood behaviour, along with their concerns and ideas for flood management and allows information to be effectively conveyed back to the community. It also provides a mechanism to inform the community about the current study and flood risk within the study area and seeks to improve their awareness and readiness for dealing with flooding.

For this study, community consultation was undertaken through various approaches at key stages of the study. The main consultation elements for this study are:

- A press release and letter introducing the project to the community and keeping them updated;
- A questionnaire sent to the community in digital and hard copy format;
- A project website for the study which was updated at various stages;

This process ensures that community participation is maximised during the development of the study. A copy of the consultation material is provided in **Appendix C**.

4.1 Project Website

A project website was published by Cardno to inform the community of the flood management process and how they could participate in it. It also included the details of the study area, the future steps and details of relevant contacts. The website address is:

https://extranet.cardno.com/bwec/SitePages/Home.aspx.

It has been developed to provide the community with detailed information about the study and gather information. The website was updated during the duration of the project to provide relevant information at each stage of the study.

4.2 Community Letter and Questionnaire

A letter and questionnaire were created to inform the community about the project and to gain an understanding of their experience with historical flooding in the catchment. The letter invited residents to participate in the study via the questionnaire by providing information on past floods in the catchment, flooding issues of concern, and ideas on reducing existing flood problems. The newsletter provided an outline of the Study Process and the importance of the community consultation.

The questionnaire sought information of historical flooding events and the effect of resident's properties. It was also advertised on Council's website and an on-line version of the questionnaire was created on the Survey Monkey website. A copy of the consultation questionnaire was also made available on the website.

The survey was distributed to all residents and business owners within the study area catchment, a total of 2223 properties. There were 369 responses - 315 as physical questionnaires and 54 through the online Survey Monkey questionnaire.

4.2.1 Demographic Information

Residents were asked to provide information about their current address and the time of residence in the Study Area. Community responses are shown in **Figure 4-1** and indicate the following:

- From the responses, the vast majority of properties (96%) were defined as residential and only 2% as commercial. Majority of properties are owner occupied (93%) with only 3% leased to tenants and 2% identified as rental.
- On average, respondents have lived in the catchment for over 10 years, with the majority of respondents having have resided in their property longer than 20 years (39%).
- 31% of respondents either experienced direct flooding impacts or had seen flooding within the adjacent properties and roads.

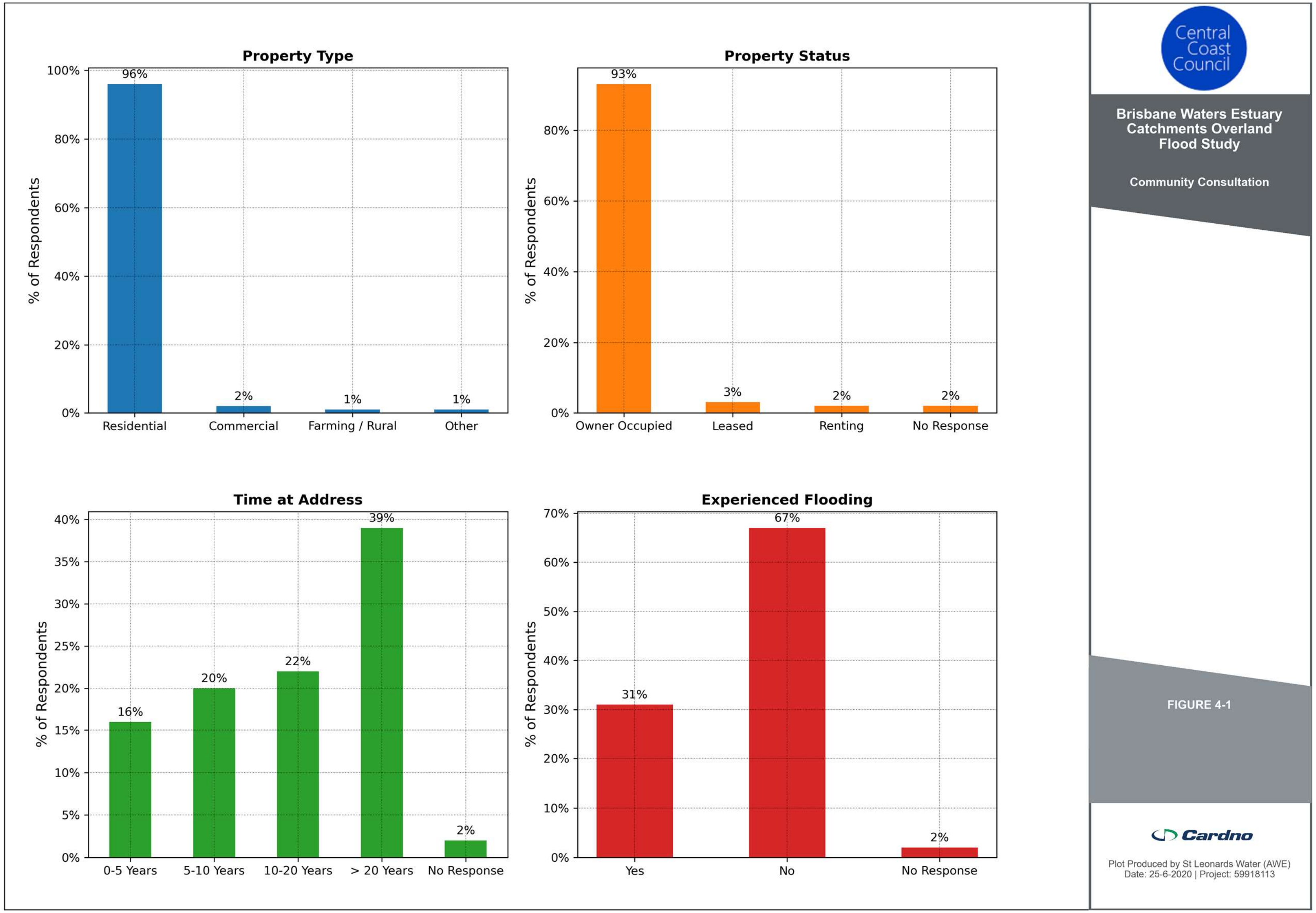


Figure 4-1 Demographic Information

4.2.2 Community Flood Experiences

Respondents were asked a variety of questions in regards to their experience of flooding within their property with aim to understand the areas and sources of flooding onto private property. The community flood experiences are visualised in **Figure 4-2** and indicate the following:

- The majority of properties (54%) were not affected by flooding. Only 4% of respondents experienced flooding above floor levels inside their property.
- A total of 16% of respondents experienced moving floodwaters within their property. Additionally, 12% of responses indicated stationary water onto private property.
- A mix of responses were obtained for the potential sources of inundation: 9% indicated mainstream flooding via the Brisbane Water Estuary and 6% of responses showed flooding due to floodwaters overtopping a nearby creek or watercourse.
- Flood markers documented within the catchment are low with only 7% of respondents indicating possession of supplementary photographs of flood events. 13% of respondents indicated the presence of any flood marks on their property.

Further flood experiences and photographs from residents and business owners in the catchment were sourced from Council and site investigation.

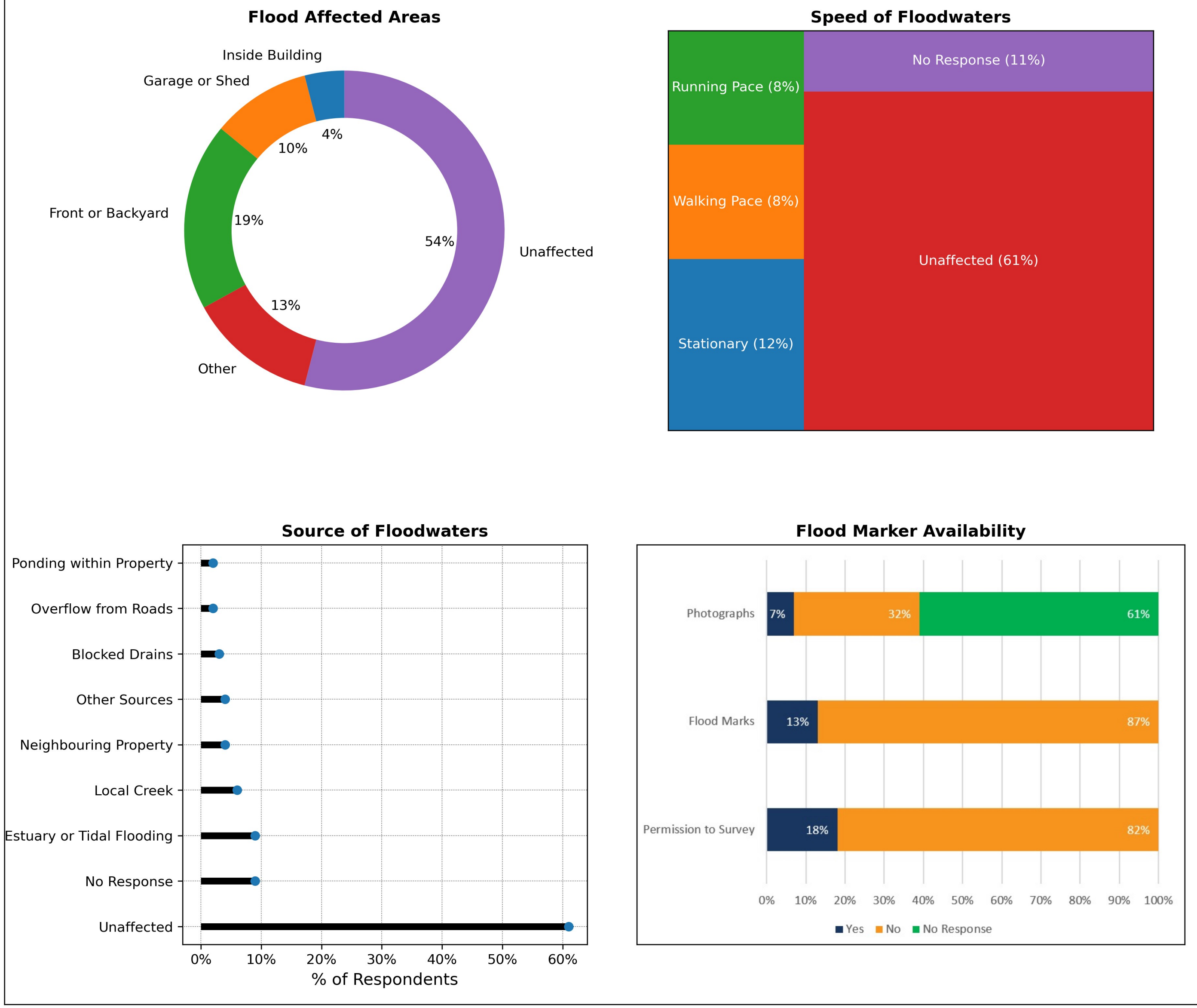
4.2.3 Historical Flooding Information

The community advised of a total of 57 levels from historical flooding events provided. These levels were given for 42 historical dates, some of which only the year was provided, and the main events with greater than four values advised are listed in **Table 4-1**.

Table 4-1 Selected Historical Storms

Storm Event	Number of Calibration Points
March 2002	3
March 2014	2
April 2015	12
March 2016	2

In consultation with Council, the four storms were decided as being critical for calibration purposes. The flood depths recorded in these storms were used to calibrate the hydraulic model. Further discussion on the calibration of the model is discussed in **Section 6**.



Central Coast Council

Brisbane Waters Estuary Catchments Overland Flood Study

Community Consultation

FIGURE 4-2

Cardno

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Figure 4-2 Community Flood Experience

5 Flood Model Establishment

Mathematical / computer models are the most common method of simulating flood behaviour within a study area to estimate characteristics such as flood levels, depths and velocities.

5.1 Hydrologic Model Development

A hydrologic model combines rainfall information with local catchment characteristics to estimate a runoff hydrograph. For this study, the 'Direct Rainfall' method (also known as "rainfall on the grid") was used for areas within the two-dimensional modelled extent and separate hydrological model was used for the validation. The XPRAFTS model used for this study has been adopted from the Brisbane Water Foreshore Flood Study (Cardno, 2008).

All durations and temporal patterns were modelled in a coarser hydraulic model with a larger grid cell size with all hydraulically important structures (such as culverts) represented. Using this model, the critical storm durations and temporal patterns were obtained to be run in the hydraulic model at a smaller cell size.

The hydrologic estimation of the direct rainfall method was verified by modelling two subcatchments in XPRAFTS.

5.2 Hydraulic Model Development

A hydraulic model estimates flood behaviour of the modelled runoff. The study area is represented as terrain and land use roughness grids in the TUFLOW software and flow is modelled overland along flow paths which develop when the capacity of channels and the drainage pipe network is exceeded.

5.2.1 Terrain

The catchment area to be modelled is digitised as a grid surface where the grid size is an important consideration for hydraulic modelling. A smaller grid size enables greater definition of overland flow paths, such as flows between buildings and along roads, however a high number of cells is thus required to define a particular study area. A 2m x 2m grid cell size was selected to balance run times and results definition for this assessment.

A terrain grid was developed based on LIDAR survey from Council and was modified in several watercourses to better represent the channel invert levels. Ground levels in the Brisbane Water estuary were adopted from bathymetry survey of the Brisbane Water Foreshore Flood Study (2008). The combined model terrain is shown in **Figure 5-1**.

5.2.2 Downstream Boundary

The study area discharges into the Brisbane Water Estuary at several main locations. The majority of areas influenced by sea level in the overland study area are limited. As a conservative estimate for modelling, a constant level was adopted across the estuary. Relevant boundary conditions for each modelling scenario were obtained from Brisbane Water Foreshore Flood Study (Cardno, 2013) and detailed in **Section 7**.

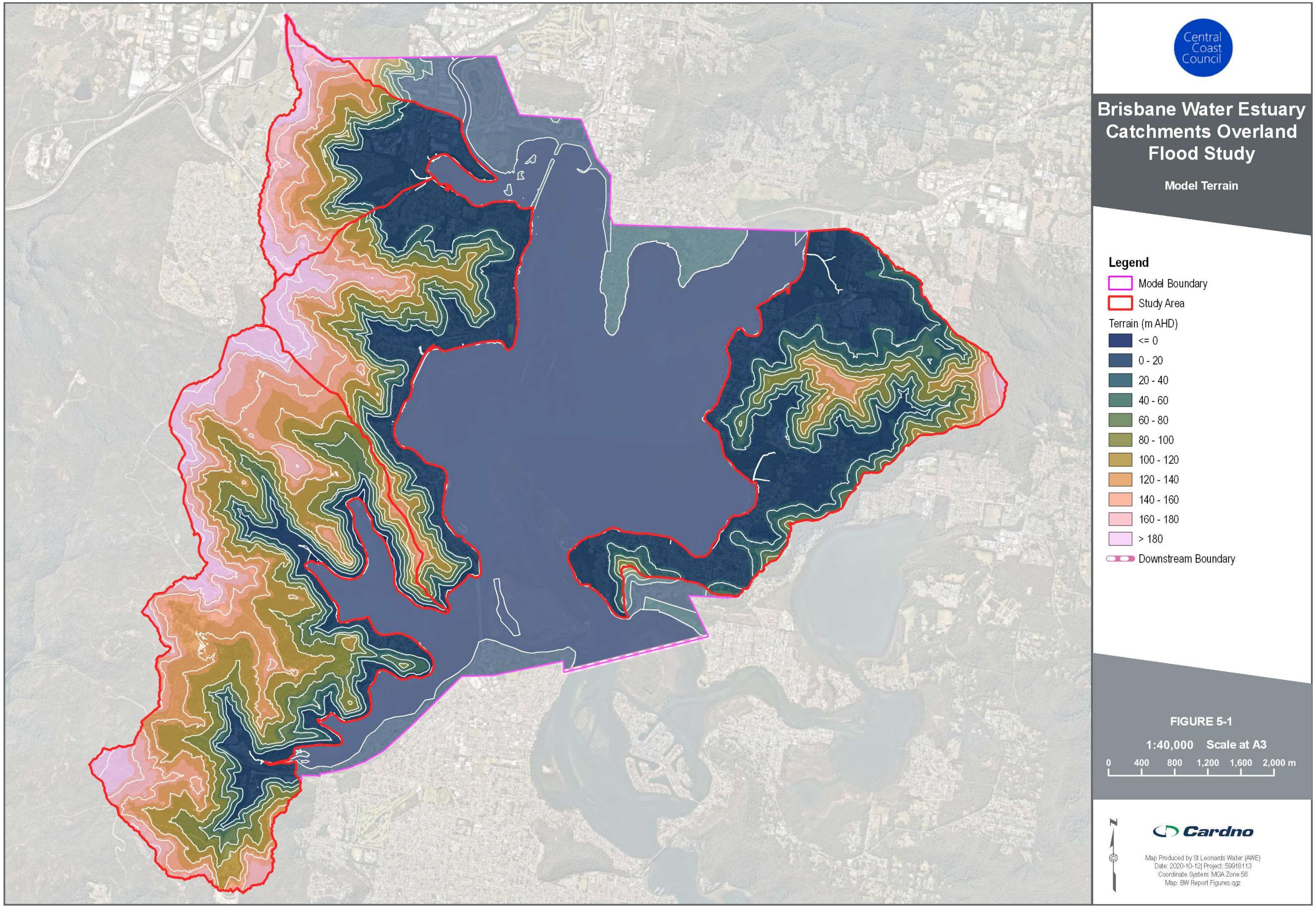


Figure 5-1 Hydraulic Model Terrain

5.2.3 Building Representation

Three common methods used to represent buildings in a hydraulic model are:

1. Raising of building footprints above the ground elevation to represent a complete obstruction to the flow;
2. Utilising a high roughness value across the footprint of the building; or
3. Using an averaged roughness value across the entire property.

A limitation of the first method is the blocking of flowpaths between buildings that are less than the grid size. Though many buildings in the study area have flowpaths between them larger than the 2m grid size, there would still be some flowpaths blocked.

The second method does not potentially block the flowpath but significantly reduces the conveyance through the building footprints. An advantage is the modelling allowance for storage within building footprints and flowpaths are maintained without requiring individual review.

The third method is to apply a composite roughness value to the entire property effectively averaging the roughness values for the building, driveways, garden areas and other property features. This is the only option for modelling if building outlines are not available. An impact of this approach is flow velocities will average out to some degree across the property.

For this study, a sensitivity analysis was undertaken to understand the impacts buildings can have on the flow paths. Based on the outcome of the analysis (discussed further in Section 8.8.1) the second method was adopted whereby building footprints are modelled with a high roughness. Building footprints from Council were applied into the model. This method allows for storage and flowpaths between the buildings to be modelled. Surface roughness values of the buildings are listed in **Table 5-1**.

5.2.4 Stormwater Pit and Pipe Network

The stormwater pit and pipe network, West Gosford Intersection Upgrade DRAINS model and work-as-executed drawings provided by Council was incorporated into the TUFLOW model as one-dimensional elements. Pit inlet capacity is governed by their dimensions and depth below terrain. An invert level of pipes was estimated where not specified based on the following formula:

$$Invert = Elevation - Pipe\ Diameter - Cover$$

Modelled pipes were reviewed for negative grades, adequate cover and pipe flow hydrographs were checked to ensure that the stormwater network was suitably represented.

5.2.5 Roughness

The flow of runoff across a surface is dependent on the nature of the specific surface, whether it is rough (inhibiting flow) or smooth (allowing easier flow). Hydraulic modelling requires mapping of the ground surface to classify the variations in roughness for the particular land use. The roughness of various areas was mapped based on land use and review of aerial imagery. Previous experience of calibrating model catchments with similar land uses and topography provides a suitable guide to determine the roughness values. The Manning's n roughness values adopted for the model are listed in **Table 5-1** and shown in **Figure 5-2**.

Table 5-1 Modelled Roughness Values

Classification	Adopted Roughness
Buildings	1
Industrial	0.02
Open Space	0.04
Residential	0.1
Roads	0.02
Stormwater Pipes (as 1D elements)	0.015
Thick Vegetation	0.1
Waterways	0.02

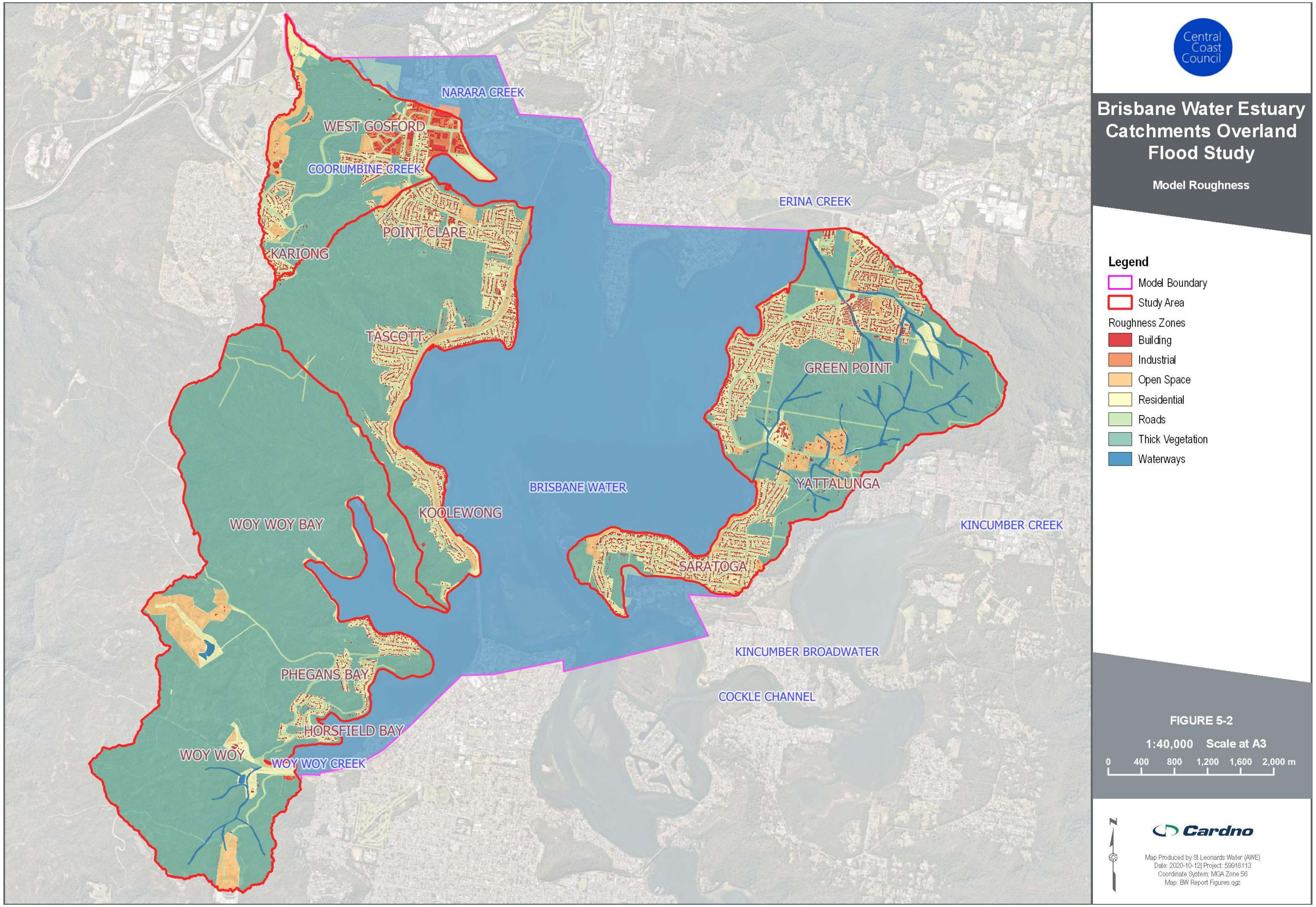


Figure 5-2 Hydraulic Model Roughness

6 Model Calibration and Validation

Validation of the flood model has been based on subcatchment hydrologic modelling and review of historical event data sourced from Council and community consultation. No stream gauges (recording a time-series of flowrates or water levels within a watercourse) operate within the study area for calibration.

6.1 Historical Storms

Four storm events were selected to validate the modelled flood behaviour to responses of the community consultation and historical flooding information of Council. The selected storms are summarised in **Table 4-1**. Historical rainfall data was available from the MHL gauges Narara Station (561085) and the Wyoming Station (561098). For each historical storm, the station with the higher rainfall was adopted for this study. Two other gauges that are close to the study area are Kincumber (561077) and Koolewong (2124301). The Koolewong gauge provides downstream water level data for historical storms. **Figure 6-1** shows the locations of the stations. The March 2002 event is estimated as the largest storm of the four events with an estimated AEP listed in **Table 6-1.** Rainfall distributions for these storms are shown in **Figure 6-2**.

Table 6-1 Validation Storm Depths and Equivalent AEP

Storm / Duration	30 min	60 min	90 min	120 min	180 min
March 2002 Depth (mm)	48	74	89	94	96
Equivalent AEP	10%-5%	10%-5%	10%-5%	10%-5%	20%-10%
March 2014 Depth (mm)	43.5	47	48.5	49	49
Equivalent AEP	20%-10%	50%-20%	50%-20%	50%-20%	100%-50%
April 2015 Depth (mm)	19	28.5	35	35.5	37
Equivalent AEP	<100%	<100%	<100%	<100%	<100%
March 2016 Depth (mm)	36	54	62	74	79
Equivalent AEP	50%-20%	50%-20%	50%-20%	20%-10%	20%

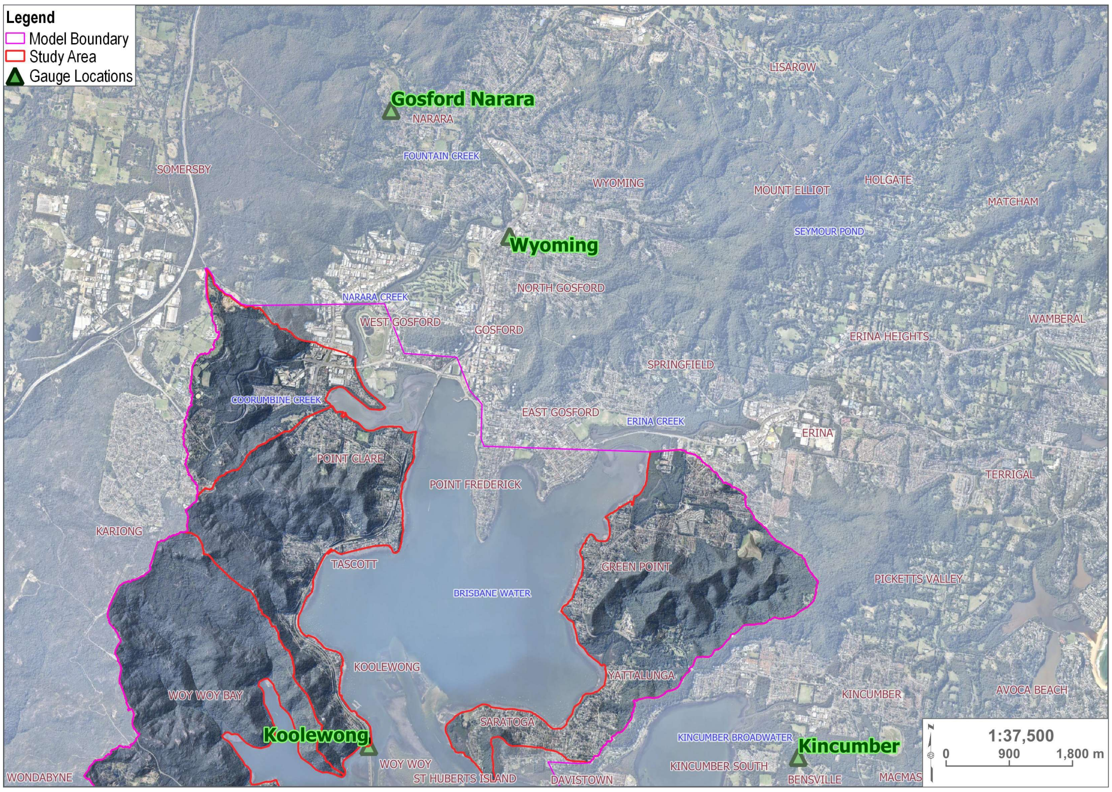
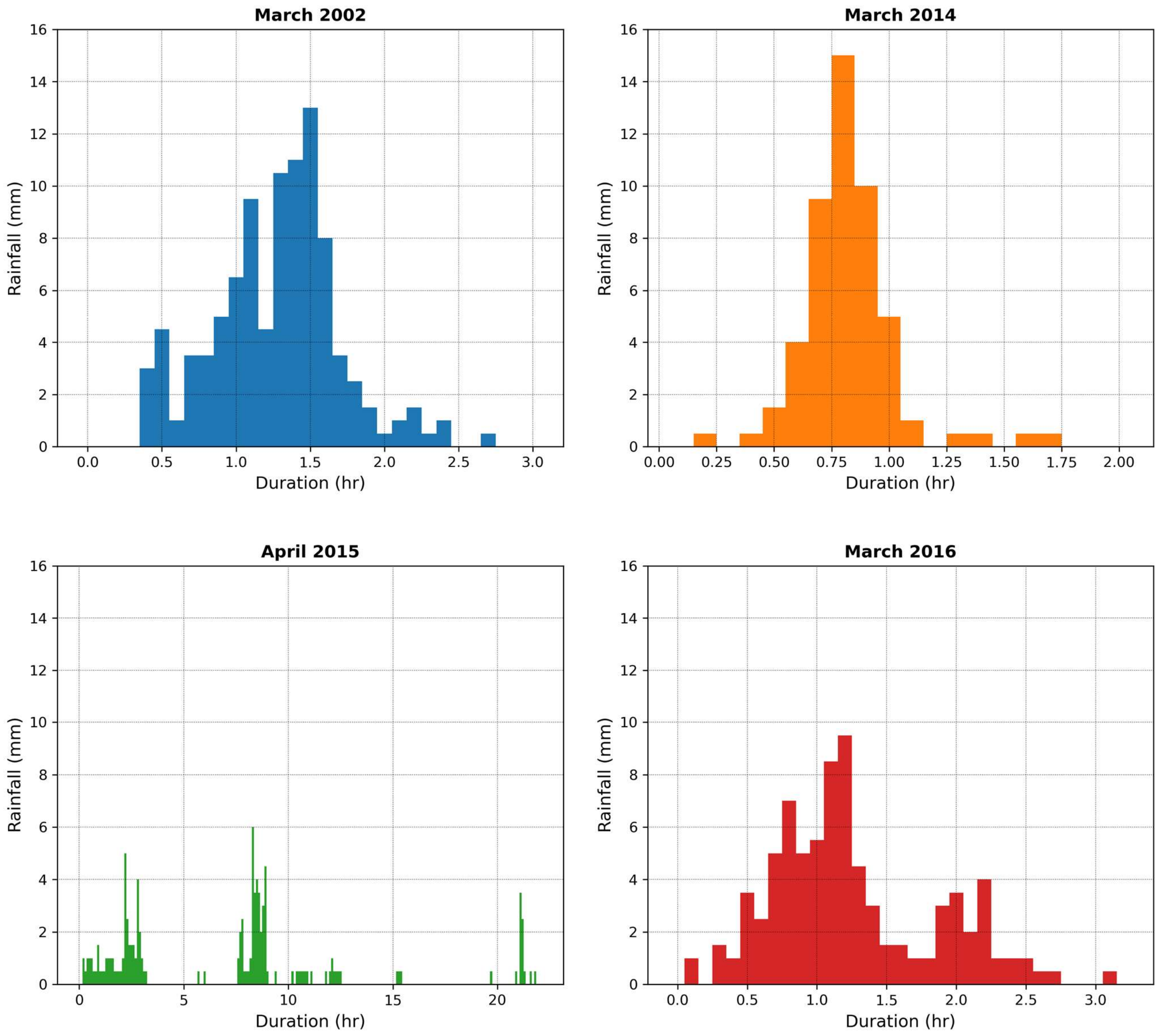


Figure 6-1 Location of MHL Rainfall Data Gauges



Central Coast Council

Brisbane Waters Estuary Catchments Overland Flood Study

Rainfall Distribution

FIGURE 6-2

Cardno

Plot Produced by St Leonards Water (AWE)
Date: 2-6-2020 | Project: 59918113

Figure 6-2 Historical Storms Rainfall Distribution

6.2 Hydraulic Model Validation

The four events described in **Section 6.1** were modelled in TUFLOW and results compared with observed levels from Council and community consultation. In general, the results show a good correlation between the observed flooding and the modelled flooding.

The hydraulic model has replicated the extents well where significant overland flow was observed. Some locations did not show the same inundation to reported observations potentially due to the specific local conditions within the property that are not represented in the model terrain, localised blockages within the stormwater network, or specific changes in the catchment over time which are not explicitly modelled.

Loss parameters for the historical storms were obtained from the XPRAFTS hydrological model used for the Brisbane Water Foreshore Flood Study (Cardno, 2013) and are summarised in
Table 6-2.

Table 6-2 Historical Storm Loss Parameters

Classification	Initial Loss (mm/hr)	Continuing Loss (mm/hr)
Buildings	0	0
Industrial	1	1
Open Space	10	2.5
Residential	5	2.5
Roads	1	0
Stormwater Pipes	0	0
Thick Vegetation	20	5
Waterways	1	0

Modelled downstream boundary levels for the historical storm events were based on recorded data from MHL at the Koolewong gauge and are shown in **Table 6-3**.

Table 6-3 Historical Storm Downstream Boundary Conditions

Storm Event	Boundary Level (m AHD)
March 2002	0.78
March 2014	0.60
April 2015	0.60
March 2016	0.60

6.2.1 March 2002 Event

The March 2002 storm was a major event in the catchment and caused significant financial damage. Refrigerated Warehouses of Australia advised inundation at their property supplying several photographs showing flood marks. Flood depths can be estimated from these photographs, shown in **Figure 6-3, Figure 6-4** and **Figure 6-5**. Hydraulic model results in this area are shown in **Figure 6-6**.

Figure 6-3 March 2002.A – Photograph Looking at Jusfrute Dr from Coorumbine Creek

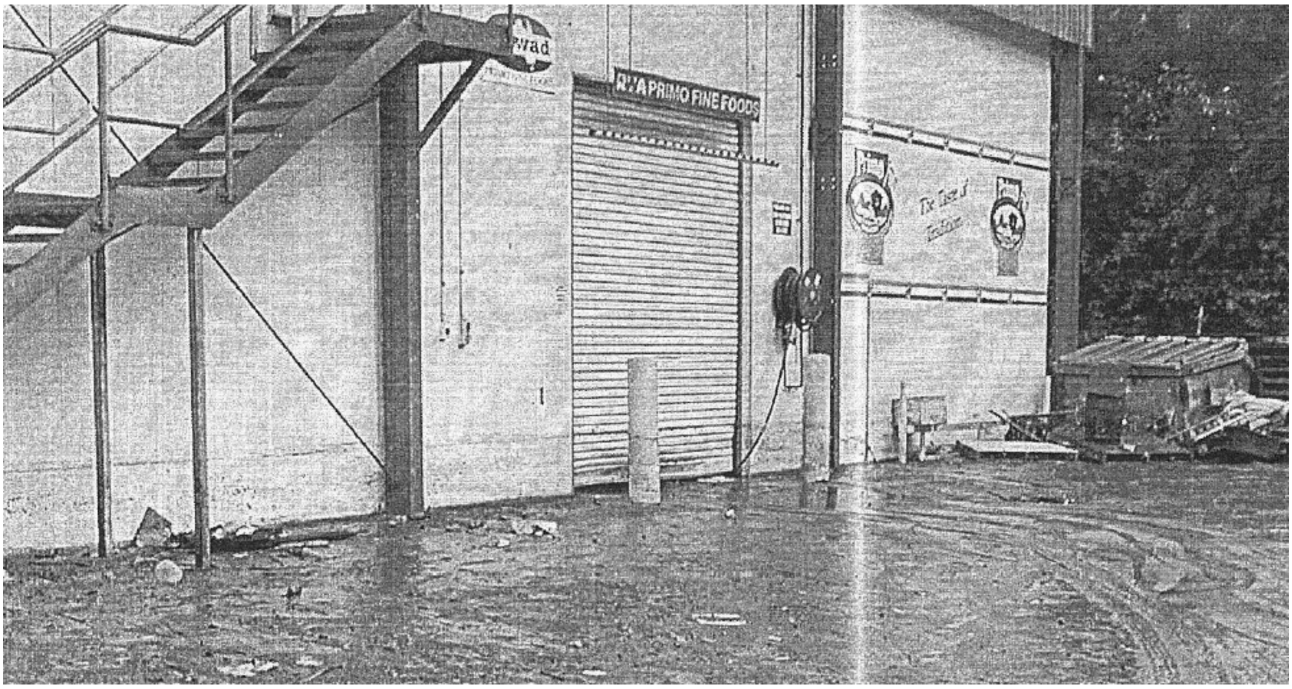


Figure 6-4 March 2002.B – Photograph Looking at Coorumbine Creek near Primo Fine Foods

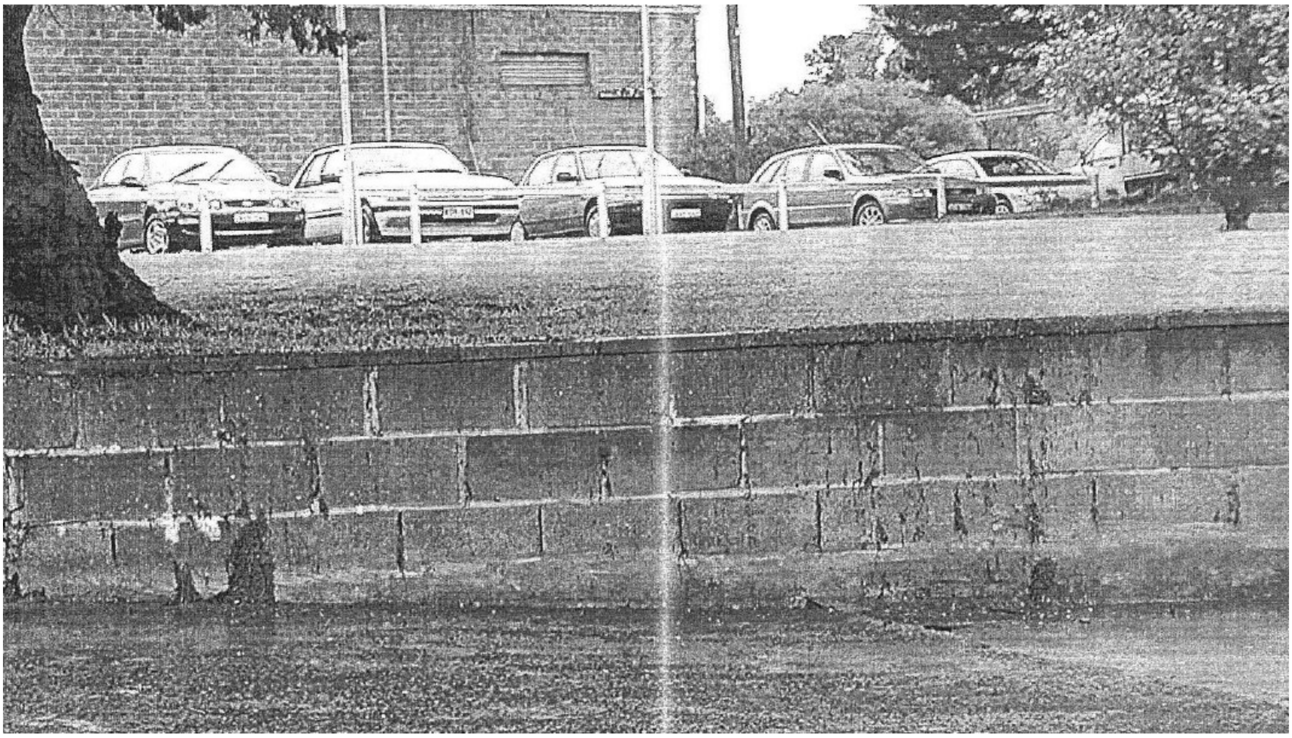


Figure 6-5 March 2002.C – Photograph Looking at Coorumbine Creek near Car Park

Figure 6-6 March 2002 – Hydraulic Model Results

6.2.2 Summary

The TUFLOW hydraulic model generally shows good agreement to the reported inundation for the four events. Results are listed in **Table 6-4** for the reference locations shown in **Figure 6-7.**

Table 6-4 Summary of Hydraulic Calibration Results

Location ID	Source	Observed Depth (m)	Modelled Depth (m)	Difference (m)	Comments
2002.A	Council	0.65	0.63	0.02	Good match.
2002.B	Council	0.40	0.39	0.01	Good match.
2002.C	Council	0.20	0.17	0.03	Good match.
2014.A	Community	0.30	0.26	0.04	Good match.
2014.B	Community	1.00	1.03	-0.03	Good match.
2015.A	Community	0.28	0.20	0.08	Detailed ground survey is required for increased certainty.
2015.B	Community	0.15	0.17	-0.02	Good match.
2015.C	Community	0.20	0.16	0.04	Good match.
2015.D	Community	0.25	0.02	0.23	Little to no inundation on site or surrounding in the modelling results.
2015.E	Community	0.30	0.16	0.14	Uncertainty on the cause of inundation. Wind fetch, ground levels and accuracy of the observation could contribute to the discrepancy.
2015.F	Community	0.10	0.12	-0.02	Good match.
2015.G	Community	0.02	0.02	0	Good match.
2015.H	Community	0.05	0.05	0	Good match.
2015.I	Community	0.07	0.08	-0.01	Good match.
2015.J	Community	0.12	0.14	-0.02	Good match.
2015.K	Community	0.10	0.10	0	Good match.
2015.L	Community	0.30	0.32	-0.02	Good match.
2016.A	Community	0.21	0.22	-0.01	Good match.
2016.B	Community	0.05	0.03	0.02	Good match.

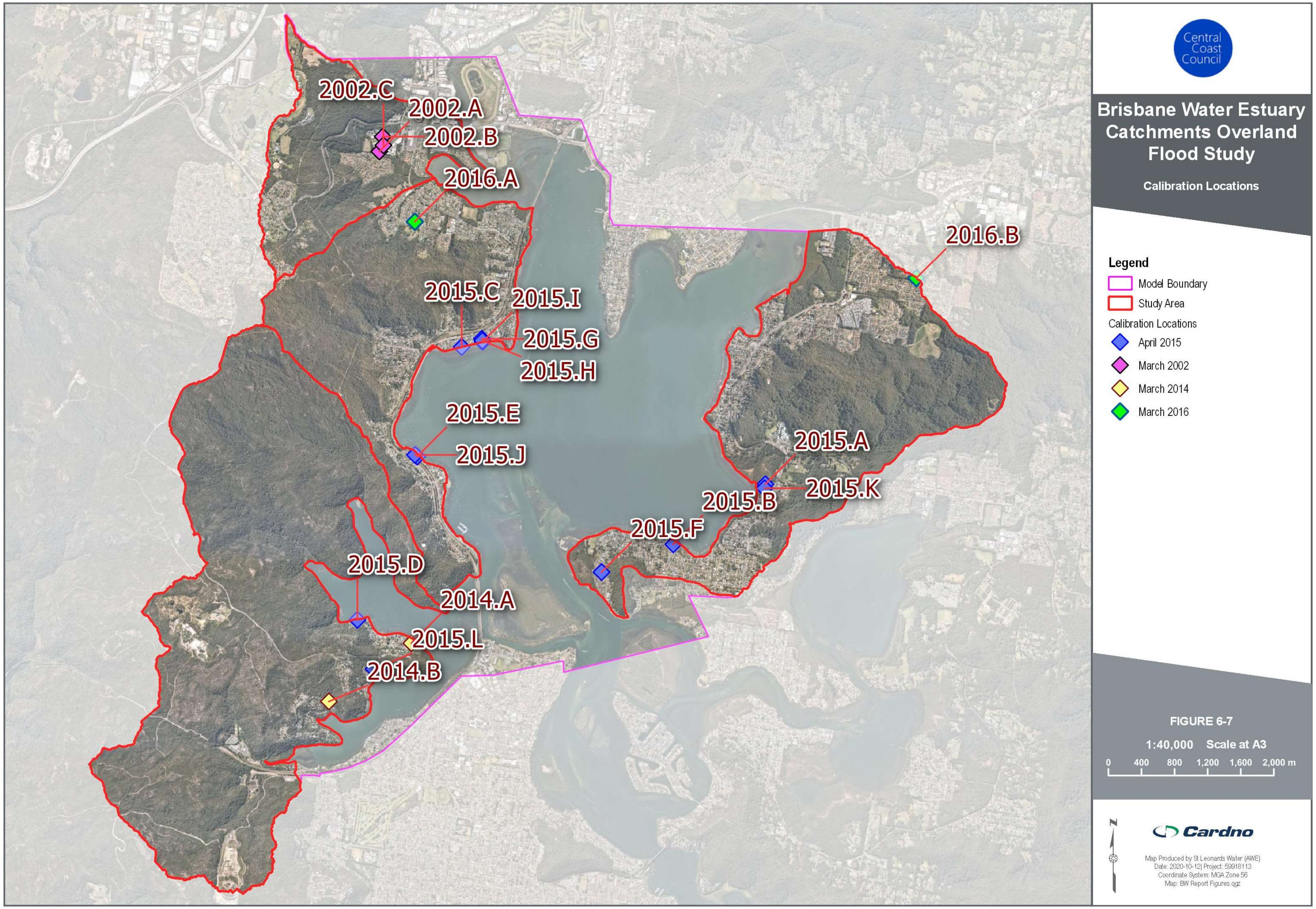


Figure 6-7 Model Calibration Locations

6.3 Hydrologic Model Validation

The hydraulic model uses a Direct Rainfall (rain-on-grid) methodology which was verified against a traditional hydrological model for two subcatchments in the study area. Verification was undertaken by comparing runoff flow hydrographs of the March 2002 calibration storm event from TUFLOW to results from a separate XPRAFTS model. It is not always expected that the two models will exactly match (in fact, two separate traditional hydrological models with similar parameters can produce significantly different results).

The two subcatchments, shown in **Figure 6-8**, are generally located in upstream areas to limit the potential variation due to modelled hydraulic controls (such as culverts) which are not in the hydrologic model.

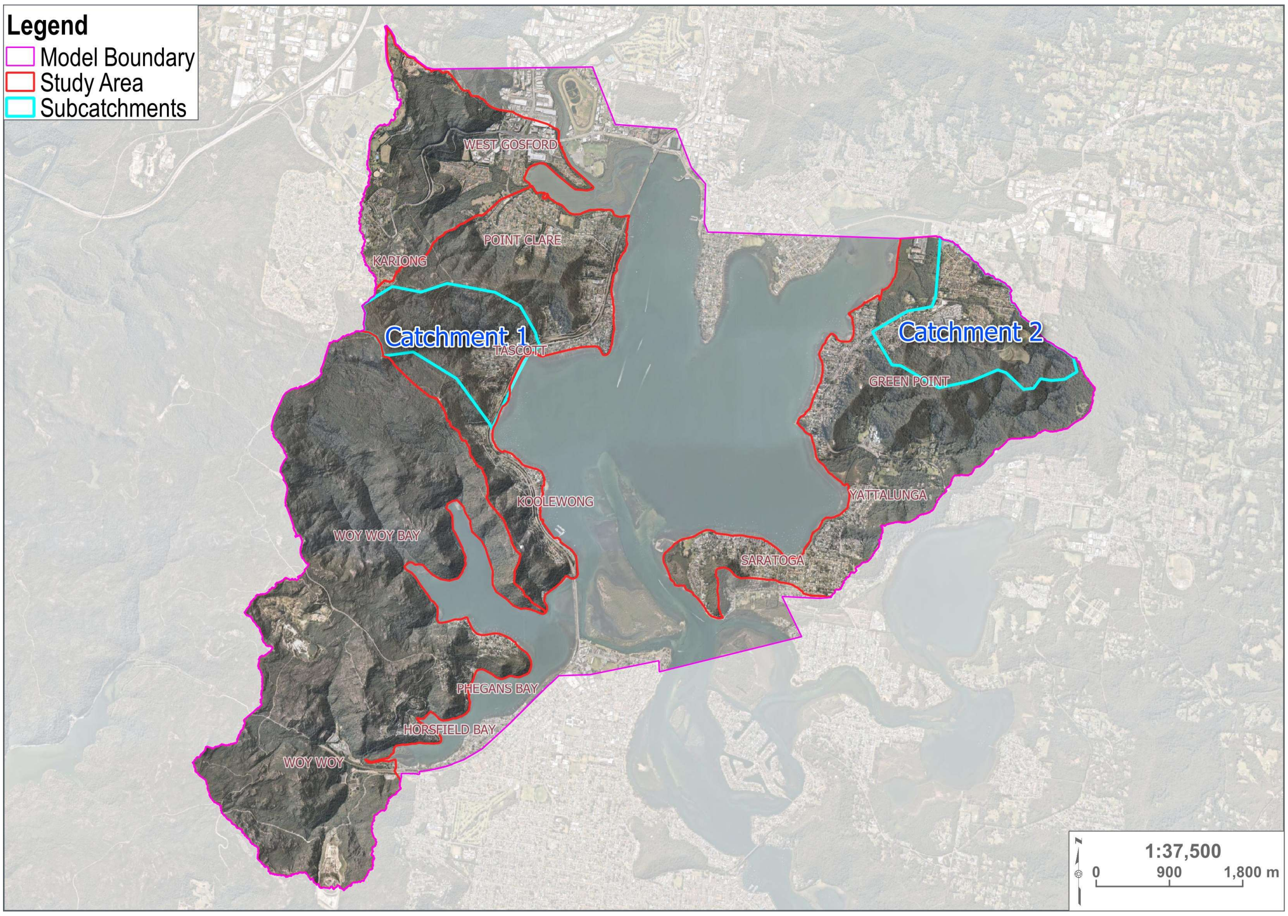
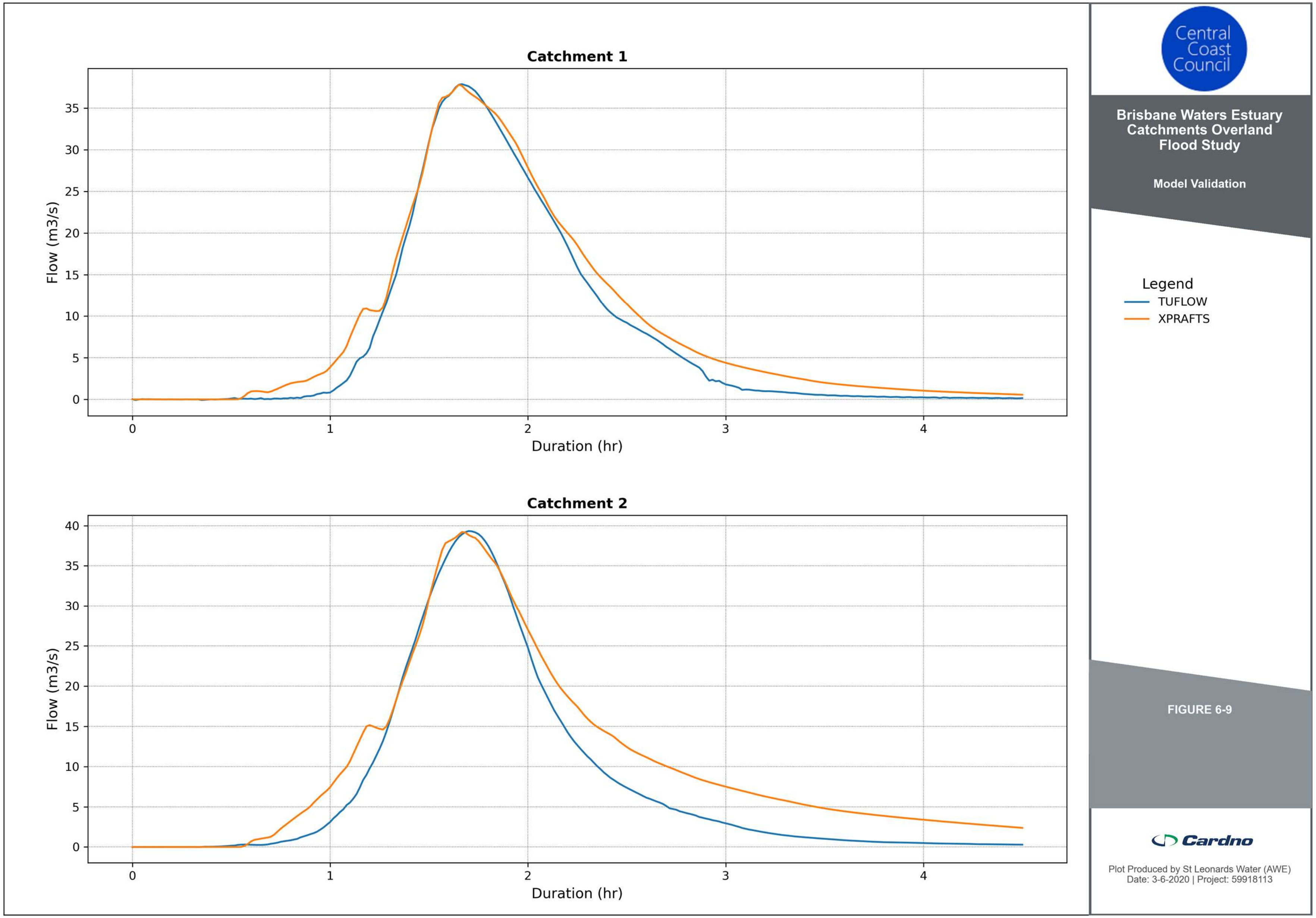


Figure 6-8 Modelled Sub Catchments

Modelled results summarised in **Table 6-5** show good agreement for the peak flow and total volume of the two models. The TUFLOW estimated volume is lower due to runoff that is retained in depressions in the terrain. Flow hydrographs modelled in TUFLOW and XPRAFTS show good agreement for the peak flow and timing of flows as shown in **Figure 6-9**. The TUFLOW model is therefore considered to suitably estimate flow runoff.

Table 6-5 Hydrologic Model Validation Summary

Sub Catchment	Area (ha)	XPRAFTS Peak Flow (m^3/s)	TUFLOW Peak Flow (m^3/s)	XPRAFTS Total Volume (m^3)	TUFLOW Total Volume (m^3)
Green Point (Catchment 2)	234	39.2	39.3	148,504	123,386
Tascott (Catchment 1)	206	37.8	37.9	137,028	122,663



Brisbane Waters Estuary Catchments Overland Flood Study

Model Validation

FIGURE 6-9

Plot Produced by St Leonards Water (AWE)
Date: 3-6-2020 | Project: 59918113

Figure 6-9 Hydrologic Model Validation Results

7 Modelling Scenarios

Large scale hydraulic modelling involves the broad scale application of parameters to estimate flood behaviour. In order to understand the impact of these parameters, several scenarios were modelled to observe the hydraulic behaviour.

7.1 Design Storms

The hydraulic model has been run for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% Annual Exceedance Probability (AEP) storm events and the Probable Maximum Flood (PMF). A storm is defined as the sum of two components:

1. Preburst – minor rainfall that starts at the start of the storm, before the design storm burst
2. Burst – the design storm event that occurs based on calculated IFDs.

$$Storm = Preburst + Burst$$

7.1.1 Loss Methodology

ARR 2019 updates the guidelines for losses within NSW. A hierarchy of loss estimation methods are recommended. The approaches for loss method selection is based on the following hierarchy:

1. Average of calibration losses from the actual study on the catchment.
2. Average calibration losses from other studies in the catchment.
3. Average calibration losses from other studies in the similar adjacent catchments.
4. NSW flood frequency analysis (FFA)-reconciled losses with appropriate scrutiny.
5. Default ARR Data Hub continuing losses with a factor of 0.4. This is used with the unmodified ARR Data Hub initial losses.

There was no calibrated loss data within the catchment or adjacent catchments. Hence, the first three methodologies were not suitable for application. There are three good quality gauges located to the north of the study area with available FFA reconciled storm losses which are shown in **Figure 7-1**. Therefore the 4th loss method was adopted for the purposes of this study. The available storm loss parameters at these gauges are summarised in **Table 7-1** below.

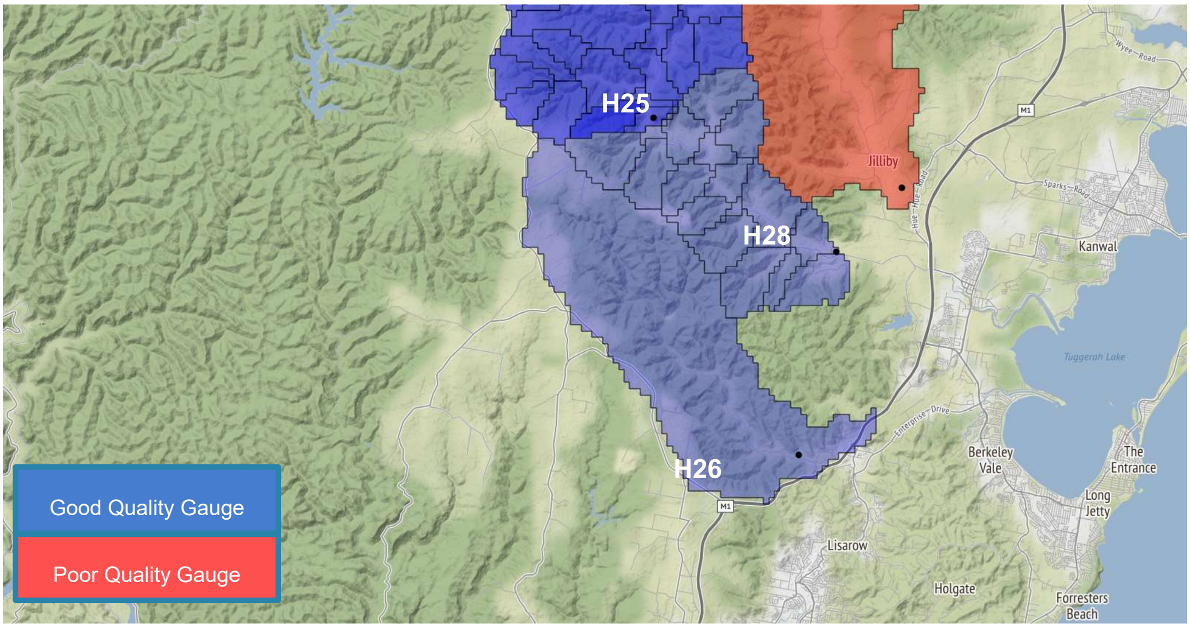


Figure 7-1 FFA Gauge locations (Source: ARR Data Hub)

Table 7-1 Loss Parameters

Station	Initial Loss (mm)	Continuing Loss (mm/hr)
Default ARR Data Hub	58	3.2
FFA 211013 [H26] (Adjacent)	64.3	4.81
FFA 211009 [H28]	50.0	3.92
FFA 211014 [H25]	18.2	5

Using these losses, flows were compared for a number of catchments in the XPRAFTS hydrologic model with high proportion of residential properties. The adjacent catchment (211013 [H26]) losses provided the most realistic flows within the range of flows expected from the FFA. Adopting the default ARR 2019 Data Hub losses is likely overestimating the flows as the storm burst depths obtained from the Narara rainfall gauge are already higher than those provided on the ARR Data Hub.

Probability Neutral Burst Initial Losses (PNBIL) from the ARR Data Hub were adopted for the storm burst loss for pervious areas such as thick vegetation and open spaces and are shown in **Table 7-2**. For durations less than 60 min, the 60 min losses were adopted. For storms with higher intensity than the 1% AEP, the 1% AEP losses were used.

Table 7-2 Probability Neutral Burst Initial Loss Parameters

Duration (min)	Burst Initial Loss (mm)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
60	30.3	16.9	16.5	17.6	18.6	17.7
90	35.2	19.8	19.3	20.3	19.5	14.5
120	34.8	18.9	18.2	19.8	19.5	16.6
180	37.7	21.5	19.1	18.8	18.1	13.0
360	33.5	20.8	19.2	16.8	15.8	11.3

Impervious areas such as building footprints and roads were found to have no initial or continuing loss capacity during the storm burst event.

For urban catchments, ARR2019 recommends specific losses in Section 3.5.3 of Book 5 for three categories:

1. Urban Effective Impervious Areas (EIA) - In urban catchments, several pervious and impervious areas are directly connected to drainage networks (example roofs and driveways). They do not contribute significantly to rainfall losses.
2. Urban Indirectly Connected Areas (ICA) - Rainfall in these areas often flows over multiple land use zones before making it into the drainage system. For example (backyards, nature strips, garden beds).
3. Urban Pervious - Parks, Ovals, Open Space corridors. GIS mapping indicates that this represents about 10% of the urban zones.

Urban land zones were modelled by mapping the effective impervious areas (EIA) and total impervious areas (TIA) within the catchment using indicative suburban areas in Green Point and Tascott. Calculations indicated that a TIA of **70%** and an EIA/TIA ratio of **60%** were representative within the study area. Using the ratios, new weighted storm burst losses can then be generated for the urban pervious areas. A standard ARR 2019 continuing loss of 2.5 mm/h was assumed for directly connected impervious urban zones.

Analysis for the critical temporal patterns and durations was performed using the approach outlined in Section 4.3.3 of the Floodplain Risk Management Guide for ARR 2016 (OEH, 2019). Mean water levels from the hydraulic analysis were used in order to select the critical durations and temporal patterns.

7.1.2 Boundary Conditions

Flood level parameters for the Brisbane Water foreshore were developed based on extensive data analysis and calibrated modelling systems. Brisbane Water Foreshore Flood Study (Cardno, 2013) calculates the PoE at various locations in the estuary. The 1% PoE level is **0.69 m AHD** at the downstream boundary of this overland flood study and has adopted for all the design storms. Slight variation in PoE exists across the Estuary due to the bathymetric data and flows from catchment flooding. It is not feasible to model a different fixed water level boundary at every flowpath and the flood behaviour in the current setup allows for full interactivity of the catchment and tidal flooding in Brisbane Water.

7.2 Climate Change

It is widely accepted that climate change will lead to increased global temperatures which will lead to increases in the intensity of rainfall as well as sea level rise. As required in the NSW Government's Floodplain Development Manual (NSW Government, 2005), this Study assesses the impact of climate change (rainfall increase and sea level rise) on flood behaviour using current industry guidelines.

Guidelines in ARR 2019 adopt the use of Representative Concentration Pathway (RCP) parameters to model climate change. RCP parameters estimate the impact on temperature and rainfall based on global climate models. Council's climate change policy (March 2015) sets targets based on RCP 8.5 which account for high carbon emissions.

Interim Climate Change Factors (obtained from the ARR Data Hub) are factored as an increase to the rainfall intensities. In addition to the rainfall intensity, the downstream boundary is also set to a higher water level to account for sea level rise. Climate change was modelled for the 1% AEP and PMF events in the hydraulic model. **Table 7-3** summarises the adopted climate change parameters for modelling.

Table 7-3 Climate Change Factors

Year	Rainfall Increase (%)	Boundary Level (m AHD)
2050	9.0	0.89
2070	14.2	1.08
2090	19.7	1.43

7.3 Coastal Interaction

Design storms use the PoE levels as downstream boundary conditions in order to simulate the Estuary flooding. Previous flood studies determined that severe flooding in the Study Area primarily occurs due to a storm surge event caused by estuarine flooding. Joint coincidence modelling was performed to understand the full envelope of flooding between the overland flows from the catchment and storm surge events in the estuary. This was done by modifying the downstream boundary conditions in the estuary. **Table 7-4** details the catchment storm events and storm surge boundary conditions derived from the Brisbane Water Foreshore Flood Study (Cardno, 2013).

Table 7-4 Coastal Interaction Scenarios

Catchment Storm Event	Storm Surge Event	Downstream Boundary (m AHD)
1% AEP	5% AEP	1.43
5% AEP	1% AEP	1.59

7.4 Sensitivity Analysis

Sensitivity analysis was undertaken to examine the impact of flood behaviour due to the variance in model parameters. The hydraulic model was run for the critical durations and temporal patterns in order to understand the impact of inputs on the 1% AEP and PMF design storms.

7.4.1 Buildings

Buildings footprints were modelled as high roughness terrain as discussed in **Section 5.2.3**. Further simulations were performed by blocking building cells to completely obstruct the flow path. This methodology reduces the storage within the site and constraints flow paths. This simulates parameters such as solid walls and raised floor levels within the site.

7.4.2 Blockage

The stormwater network in the design storms were controlled by pit inlet capacities and downstream water levels creating backwater effects. In order to observe the impact of loose material on the performance of the stormwater network, blockage factors were calculated as per ARR 2019 guidelines. Site visits and historical flooding suggests high debris availability with high transportability and mobility. Steep terrain collects loose vegetation from upstream areas of the catchment. In urbanised areas, large objects such as cars and boats can obstruct major culverts. Based on the calculations, the following blockage parameters were applied:

1. All pits were modelled with 100% inlet blockage.
2. Culverts and bridges were modelled with 25% debris blockage if the cross-section area was greater than 1.05 m diameter circular pipe.
3. For openings with cross sectional area less than 1.05 m diameter, a 50% blockage factor was applied. This approach is consistent with the adjacent catchment Narara Creek Flood Study (Golder, 2018).

7.4.3 Losses

ARR 2019 guidelines provide a complex set of losses and the adoption of those losses requires scrutiny. Burst loss parameters from **Table 6-2** were adopted for design storms instead of the approach outlined in **Section 7.1.1**.

7.4.4 Manning’s Roughness

Surface roughness within the catchment varies spatially and can be rougher or smoother based on the age and maintenance of infrastructure. Surface roughness parameters outlined within **Table 5-1** were increased and decreased by 20%. Manning’s parameters were not modified within stormwater pipes and culverts as they are generally less likely to have large variability in roughness compared to exposed surfaces and does not impact overland flow behaviour significantly.

7.4.5 Rainfall

Flood controls are set based on the 1% AEP and freeboard extents. In the adjacent Kincumber Overland Flood Study (MHL, 2014) a 30% rainfall increase was applied to the 1% AEP storm in order to obtain an indicative flood control extent. Further discussion on the comparison of this storm and its applicability is discussed in **Section 9.1**.

7.5 ARR 1987 Comparison

Comparison of the ARR 1987 methodologies was performed by using the standard ARR 1987 IFD and loss parameters in **Table 6-2**. The comparison of the methodologies was used to understand the changes in peak flood results across the catchment with respect to water levels, critical durations and extent of flooding. Comparison was performed for the 1% and 5% AEP storm events.

7.6 Levee Assessment

The Brisbane Water Floodplain Risk Management Study (Cardno 2015) concluded that the highest amount of flood damages within the estuary is due to tidal inundation. High water levels within the estuary pose a risk to a large number of waterfront properties. With climate change effects, this risk is set to increase and protective measures can help in preparing against the rising sea levels.

A sensitivity analysis was conducted by assessing a set of levees to act as barriers to flood waters around the waterfront to protect properties and critical infrastructure to address existing and future flood risks. The location of the levees was determined to target low lying residential properties. Levee heights are set to the 1% AEP storm surge event peak water level determined from the Brisbane Water Foreshore Flood Study (Cardno, 2013) which ranges from 1.6 – 1.8m AHD. The pipes under the levees were assumed to only flow out into the estuary using flow control valves to prevent backwater flows from the estuary inundating properties upstream of the proposed levee.

The effectiveness of the levees were determined based on the 1% and 20% AEP storms. The high water (HHWSS) level at the Koolewong gauge was adopted for this assessment. Climate change parameters for the years 2050 and 2090 were used to understand the effectiveness of the levee into the future. The scenarios are summarised in **Table 7-5**. Proposed levee locations are shown in **Figure 7-2**.

The levee assessment has been undertaken to assist Council in the preparation of a future Floodplain Risk Management Study and Plan or other strategic planning to review the effect of barriers on catchment flood behaviour.

Table 7-5 Levee Scenarios

Scenario	Catchment Storm	Estuary Level
1 – Existing Conditions	1% AEP	0.623
2 – 2050	1% AEP	0.823
3 – 2090	1% AEP	1.363
4 – Existing Conditions	20% AEP	0.623
5 – 2050	20% AEP	0.823
6 – 2090	20% AEP	1.363

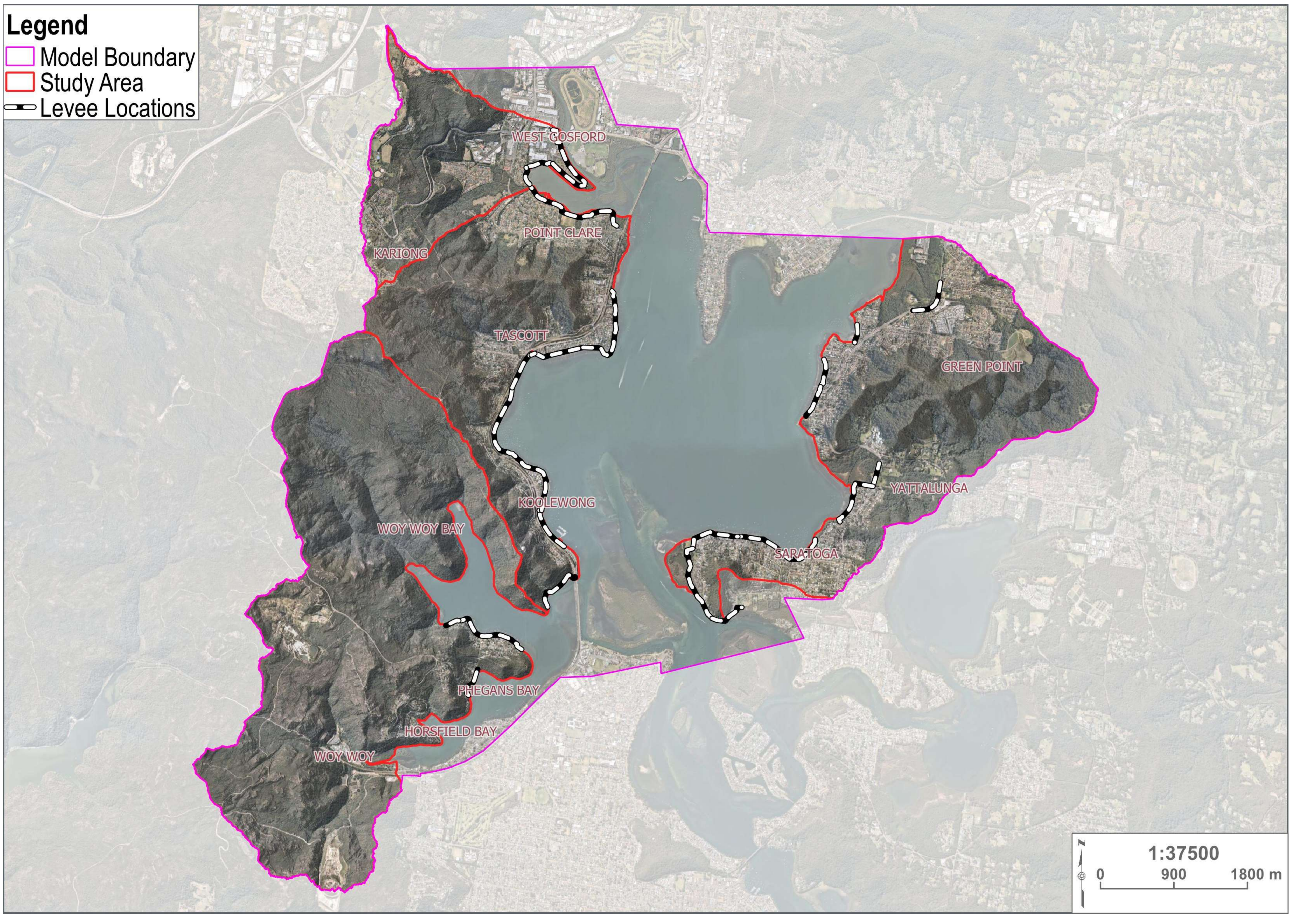


Figure 7-2 Proposed Levee Locations

8 Results

This section outlines the observations of flood behaviour based on the various modelling scenarios within the catchment. Rainfall on grid modelling shows inundation on every grid cell within the study area, thus lood results were filtered for maps to emphasise the flow paths and identify the significant areas of flooding based on the following criteria:

1. Depth > 0.10m; OR
2. Depth > 0.05m AND Velocity x Depth > $0.025m^2/s$; OR
3. Velocity > 2m/s
4. Area of flooding greater than 100 m^2

Flood behaviour for various design storms has been mapped using the filtering criteria in the Appendices outlined in **Table 8-1**.

Table 8-1 Flood Model Results

Scenario	Result	Events	Reference
Design	Critical Duration	50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% and PMF	**Appendix E**
	Depth, Water Level and Velocity		**Appendix F**
	Velocity Depth Product, Provisional Hazard, General Hazard and Hydraulic Categories		**Appendix G**
	Stormwater Network Capacity		**Appendix H**
Coastal Interaction	Water Level Differences	1% and 5% AEP	**Appendix I**
Climate Change		1% AEP and PMF	**Appendix J**
Sensitivity Analysis		1% AEP and PMF	**Appendix K**
ARR 1987		1% and 5% AEP	**Appendix L**
Levee Assessment		1% and 20% AEP	**Appendix M**

8.2 Water Levels, Depths and Velocities

Several shallow flow paths form within the study area and flow into the estuary through existing creeks and channels. High roughness zones on building footprints detain water and exhibit isolated flood areas. Results indicate flood behaviour up to the 5% AEP largely contained within the existing flow paths. In the West Gosford and Coorumbine Creek area, several overland flow paths are observed and a confluence is formed upstream of Brisbane Water Drive.

For storm intensities in 2% AEP storms and greater, floodwaters start overtopping established flow paths and channel banks. Due to the flat topography, several areas of ponding are observed in residential areas towards the waterfront as floodwaters have insufficient velocity to drain via a flow path. As a result, the flood extents start to widen and impact more properties. Major road infrastructure starts to inundate with greater depths making it difficult for access and evacuation. This is a concern in the Tascott area where Glenrock Parade is inundated as the raised railway embankment holds water back. In a PMF event, high flood depths are observed on major roads and residential areas. The depths at key road locations from **Figure 8-1** are reported in **Table 8-2**.

Locations were identified which exhibit potential flooding issues for the residents and businesses in the Green Point catchment. They should be investigated further if development is proposed in the floodplain:

- Broadlands Green Point - Retirement homes and communities are located upstream of Avoca Drive along an unnamed watercourse. Avoca Drive forms an embankment for the watercourse and floodwaters are conveyed via a series of culverts under properties and roads. The undersized culverts under Avoca Drive result in a build up of floodwaters onto newly developed retirement homes.
- Avoca Drive and Davistown Road Roundabout, Green Point – This junction forms a bottleneck for the access of rescue and evacuation services in the Yattalunga and Saratoga areas due to high flood depths. An unnamed watercourse flows under Davistown Road and joins into Egan Gully, however the current set of culverts are unable to effectively convey floodwaters resulting in the overtopping of the roads.

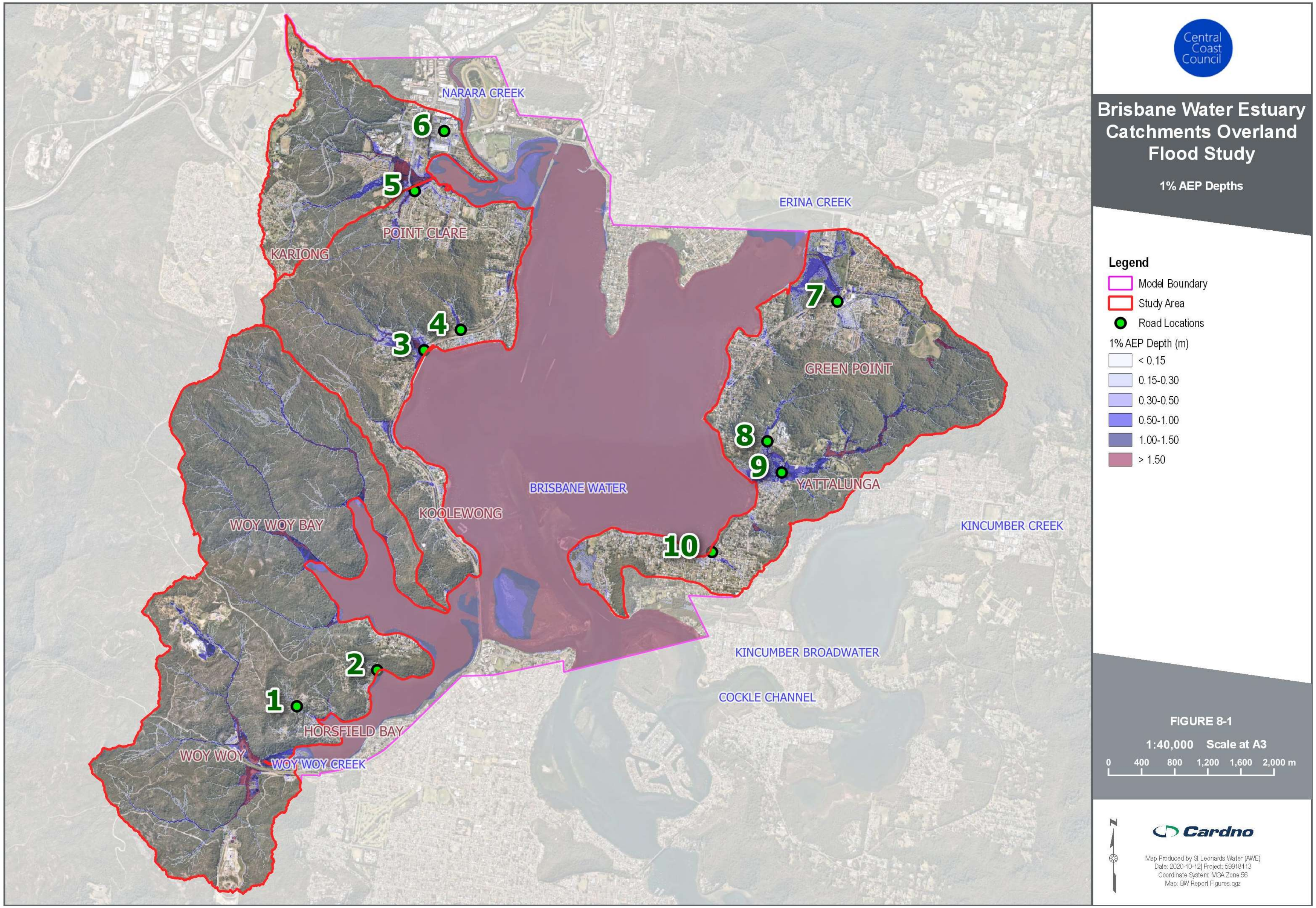


Figure 8-1 1% AEP Flood Depths

Table 8-2 Road Inundation in Storm Events

ID	Location	Flood Depth (m)						
		50% AEP	20% AEP	5% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1	Woy Woy Road, Woy Woy	0.1	0.2	0.5	0.6	0.7	0.7	1.1
2	Phegans Bay Road, Woy Woy	0.1	0.2	0.3	0.3	0.3	0.4	0.6
3	Glenrock Parade (near Tascott Station)	0	0.1	0.3	0.6	0.9	1	1.5
4	Glenrock Parade (near Melaleuca Park)	0	0.2	0.8	1.5	2	2.4	4.2
5	Brisbane Water Drive, Point Clare	0	0.1	0.2	0.6	0.8	1	1.9
6	Central Coast Highway, West Gosford	0.3	0.5	0.5	0.6	0.6	0.6	0.8
7	Avoca Drive (near Coles Green Point)	0	0.1	0.1	0.1	0.1	0.1	0.3
8	Avoca Drive (near Egan Gully)	0	0.1	0.2	0.3	0.4	0.5	0.9
9	Davistown Road, Yattalunga	0	0.2	0.3	0.5	0.6	0.7	1.2
10	Mimosa Ave, Saratoga	0.1	0.1	0.2	0.2	0.3	0.3	0.5

The Tascott catchment drains through multiple flow paths into the Estuary. The flowpaths are bounded by Glenrock Parade, Brisbane Water Drive and railway line effectively creating basins. This forces the floodwaters into confined bridge crossings and culverts that result in pressurised flows. Upstream of the estuary, backwater effects are observed which result in a widening of the floodplain onto private properties and the inundation of major roads. **Figure 8-2** indicates flooding in the Koolewong suburb and detention of floodwaters as a result of the railway corridor.

Figure 8-2 Flood Depths at Koolewong

8.3 Critical Duration and Temporal Pattern

The coarse hydraulic model was used to obtain representative critical durations and temporal patterns within the catchment. Spatial variation of the patterns was addressed by focusing on flow paths in urbanised locations within the study area. Box plots were used to visualise the variation in flows based on storm duration and temporal pattern and are shown in **Appendix E**. Mean values were used to select the critical durations and their closest representative temporal pattern.

Critical durations for all design storm AEPs are summarised in **Table 8-3**. The maximum values were enveloped from each duration to represent the peak flooding for each event. Generally, flooding within the catchment occurs up to 120 mins or less. The PMF event is has a critical duration of up to 60 mins in the downstream areas of the catchment.

Table 8-3 Critical Duration and Temporal Pattern

Event	Critical Duration (min)	Temporal Pattern
50% AEP	15	TP05
	45	TP10
	60	TP06
	120	TP08
	360	TP09
20% AEP	15	TP05
	45	TP06
	60	TP03
	120	TP10
10% AEP	15	TP04
	60	TP07
	120	TP02
5% AEP	15	TP04
	60	TP06
	120	TP06
2% AEP	60	TP08
	120	TP02
1% AEP	120	TP02
0.5% AEP	120	TP02
0.2% AEP	120	TP02
PMF	15, 30, 45 and 60	GSDM

8.4 Flood Hazard and Hydraulic Categories

Flood hazard was assessed across the study area based on a combination of velocity and depth of floodwaters. Two flood hazard criteria were used in order to assess the risk of floodwaters on people and property. A further relationship between velocity and depth was used to map the hydraulic categorisation (flood function) in all design storms. The various hazards are mapped in **Appendix G**.

8.4.1 Provisional Hazard

Criteria for provisional hazard has been taken from the NSW Floodplain Development Manual (NSW Government, 2005) which defines provisional hazard as one of three categories – low, transitional and high. The provisional hazard curves are shown in **Figure 8-3**. Modelling indicates that most residential properties are impacted by low hazard zones in the catchment. Higher hazards are primarily only seen along creek corridors as shown in **Figure 8-4** for Horsfield Bay and Phegans Bay areas in the Woy Woy Bay catchment.

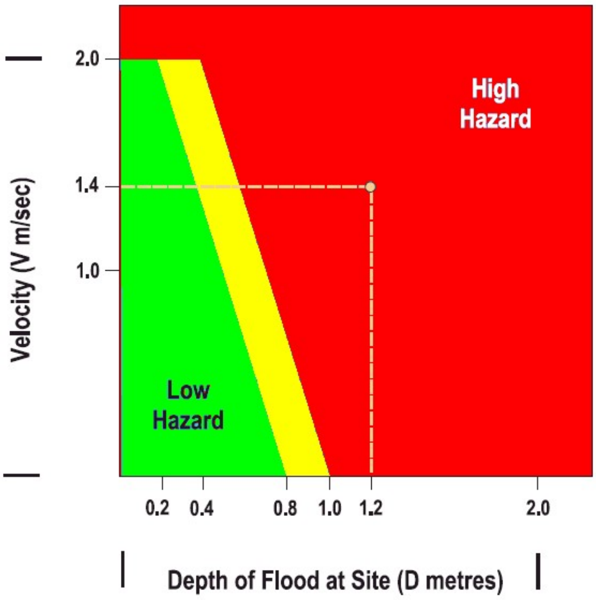


Figure 8-3 Provisional Hazard Curves

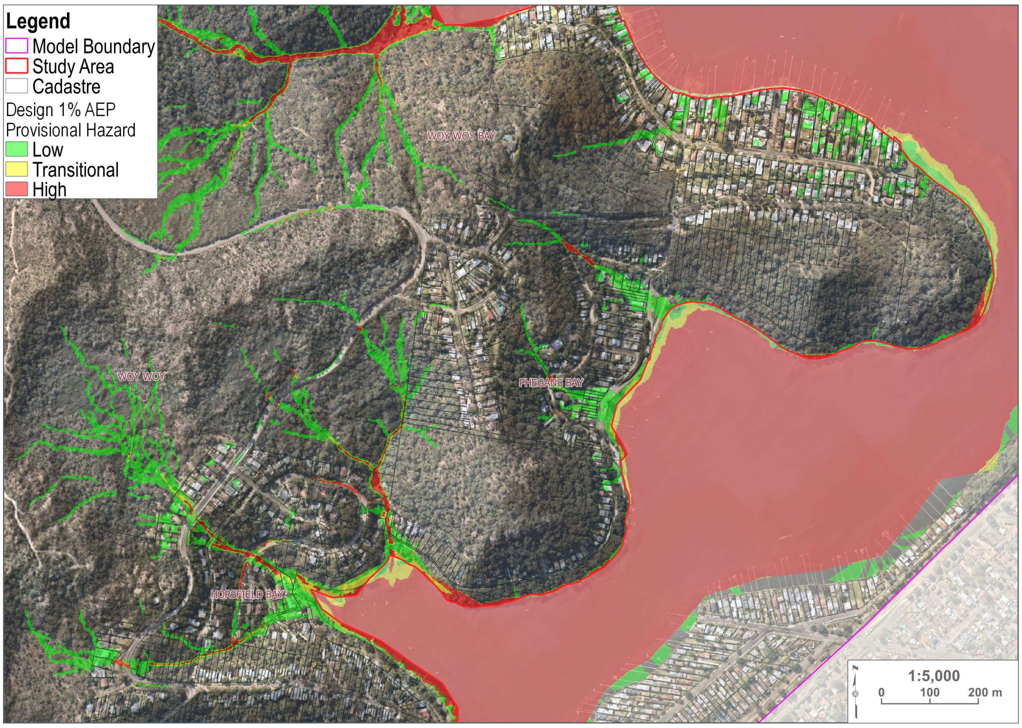


Figure 8-4 Provisional Hazard at Woy Woy Bay

8.4.2 General Hazard (Combined Hazard Curves H1-H6)

Further research into the relationship between the product of the velocity and depth of floodwaters has provided information on the stability of structures and vehicles. Additionally, the impact of floodwaters on children, adults and elderly has also been investigated. Guidance from the Technical Flood Risk Management Guideline (Australian Emergency Management Institute, 2014) classifies hazard into six categories from H1 (least hazard) to H6 (highest hazard). Book 6, Chapter 7 of the ARR 2019 guidelines support the use of these curves for risk management. The general hazard curves are shown in **Figure 8-5**.

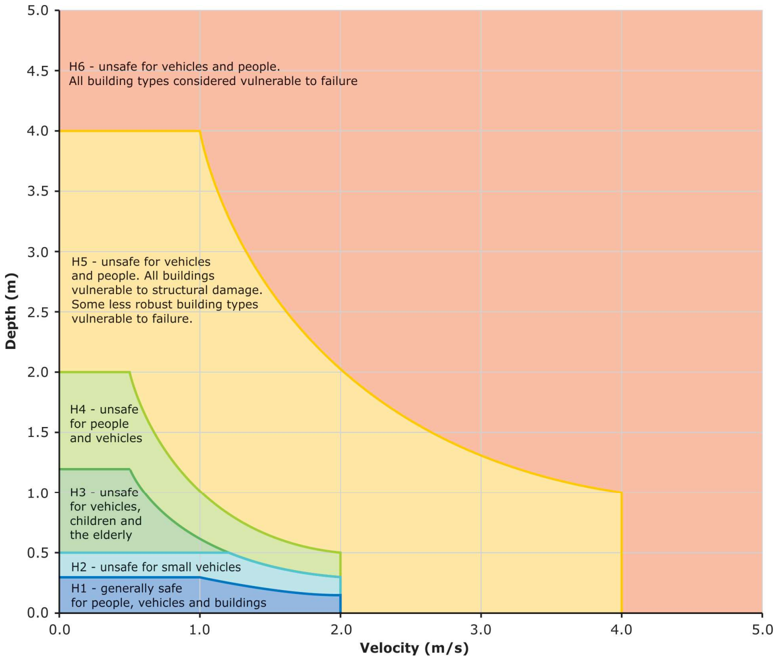


Figure 8-5 General Hazard Curves

Results indicate high hazard in all major waterways and along most flow paths. Overland flooding is generally low hazard due to shallow depths up to the 5% AEP event. Velocities along the flow paths are generally high along the upstream steep areas but lowered in the flattish terrain areas such as West Gosford. As higher flood depths and velocities develop, high hazards are observed along the roads and residential areas. **Figure 8-6** shows prevalence of H3 to H5 hazard zones along the Yattalunga flow path.

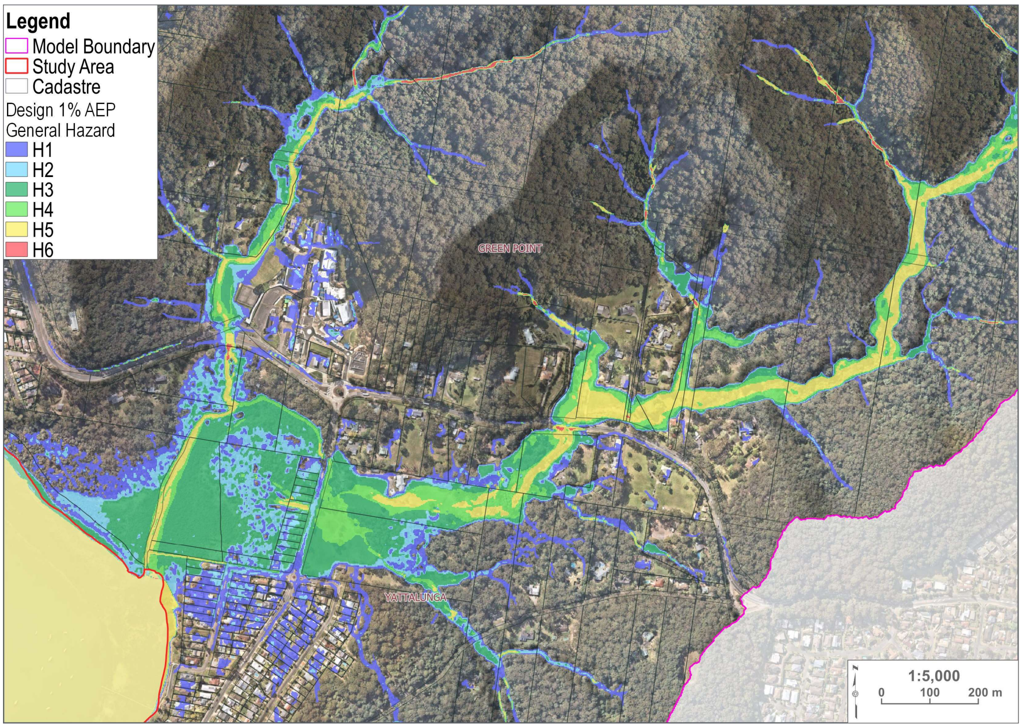


Figure 8-6 General Hazard in Yattalunga

8.4.3 Hydraulic Categories (Flood Function)

Hydraulic categorisation (also referred to as flood function) of the floodplain is used in the development of the Floodplain Risk Management Plan. Flood prone land is defined to be one of the following categories:

- **Floodway** - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- **Flood Storage** - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- **Flood Fringe** - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern.

Floodways were determined by considering branches that if blocked or removed, would cause a significant redistribution of the flow. The following criteria were used to define a floodway (Howells et al, 2003):

- Velocity x Depth product must be greater than 0.25 m^2/s and velocity must be greater than 0.25 m/s; OR,
- Velocity is greater than 1 m/s.

The criteria used to determine the flood storage is:

- Depth greater than 0.2m
- Not classified as floodway.

All areas that were not categorised as Floodway or Flood Storage, but still fell within the flood extent, are represented as Flood Fringe.

Results show similar relationship between the floodways and high hazard zones. Several areas of flood fringe are observed due to low flood depths in overland flows. **Figure 8-7** shows the hydraulic categorisation in Green Point. Several floodways are observed along minor watercourses and swales.

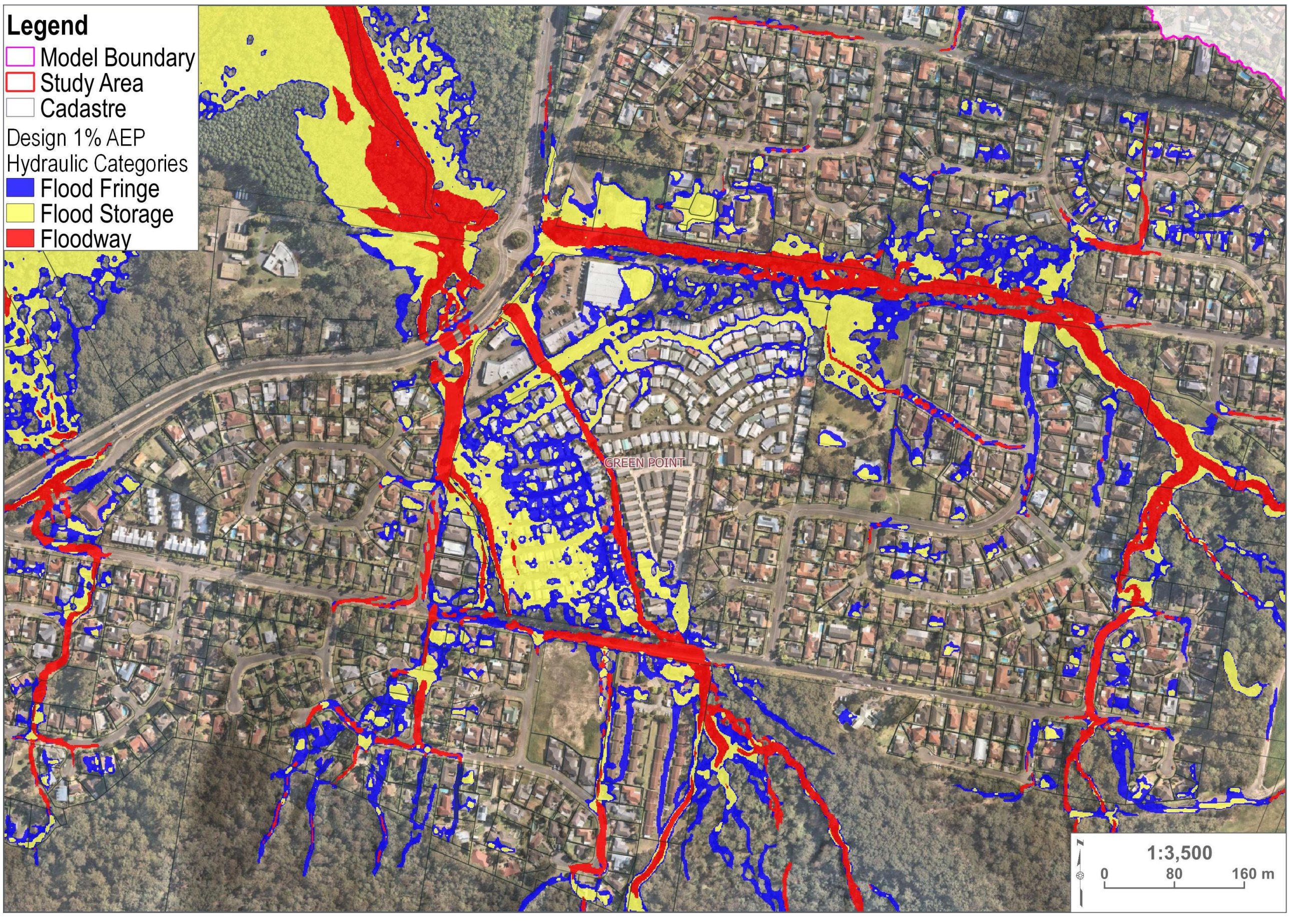


Figure 8-7 Hydraulic Categorisation at Green Point

8.5 Stormwater Network Capacity

Overland flows are captured by the pits and culverts and transferred to the estuary via Council's stormwater network. In low lying areas, flat terrain reduces the slope of the pipes resulting in lower flow velocities in the network. Additionally, the pipes experience backwater effects from the estuary, effectively reducing their capacity at the downstream nodes.

Capacities and flows within the network were determined for the critical durations and temporal patterns for all AEPs. The number of pipes running at 100% capacity within each event are summarised in **Table 8-4**.

Table 8-4 Stormwater Network Capacity

Storm	Pipes Running More than 50% Full (%)	Pipes Running 100% Full (%)
50% AEP	31	17
20% AEP	44	28
10% AEP	47	32
5% AEP	50	36
2% AEP	50	37
1% AEP	53	39
0.5% AEP	56	41
0.2% AEP	58	43
PMF	73	58

Results indicate that 17% of the stormwater network is already full in a minor storm event such as 50% AEP. Pipes in the upstream areas of the catchment generally do not reach full capacity as they are controlled by the inlet capacity of pits. Additionally, sufficient pipe slopes and the lack of backwater allows for floodwaters to drain into more downstream areas of the catchment. During more intense events, the downstream pipes of the network are running at full capacity and unable to provide sufficient conveyance of floodwaters into the estuary. This is observed in **Figure 8-8** at the Coorumbine Creek and West Gosford catchments.

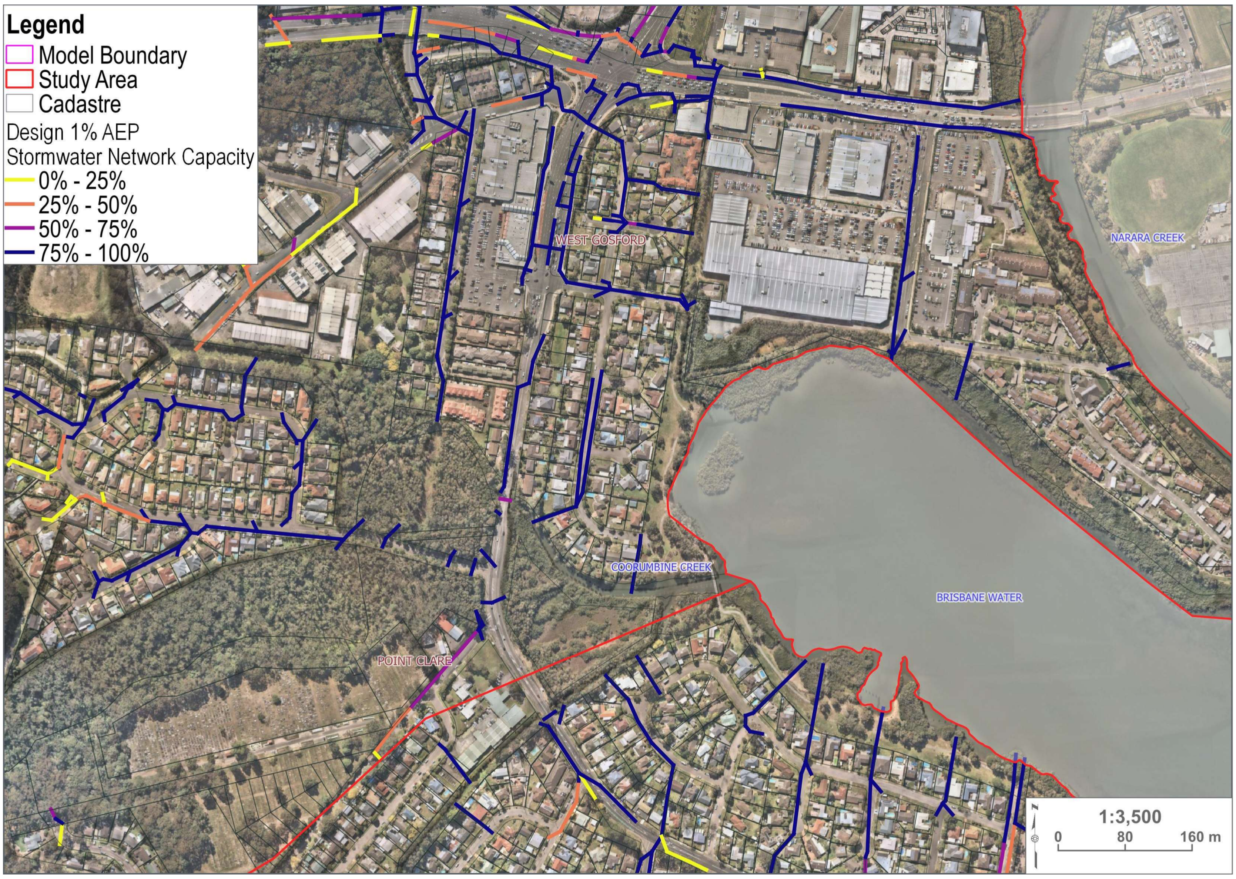


Figure 8-8 Stormwater Network Capacity at West Gosford

8.6 Coastal Interaction

Joint probability modelling suggests that the storm surge event causes high flood levels in the downstream areas of the model. The envelope of the catchment storm and the storm surge events indicate that the wider extent is caused primarily by tidal influence. Coastal interaction mapping is provided in **Appendix I**.

Some waterfront properties in the Woy Woy and Green Point catchments are inundated due to the storm surge event only. **Figure 8-9** shows the difference in flood levels in the Yattalunga and Saratoga areas due to the 5% AEP storm surge event occurring at the same time as the 1% AEP catchment flood. Additional inundation is experienced along Mundoora Ave and Steyne Road.

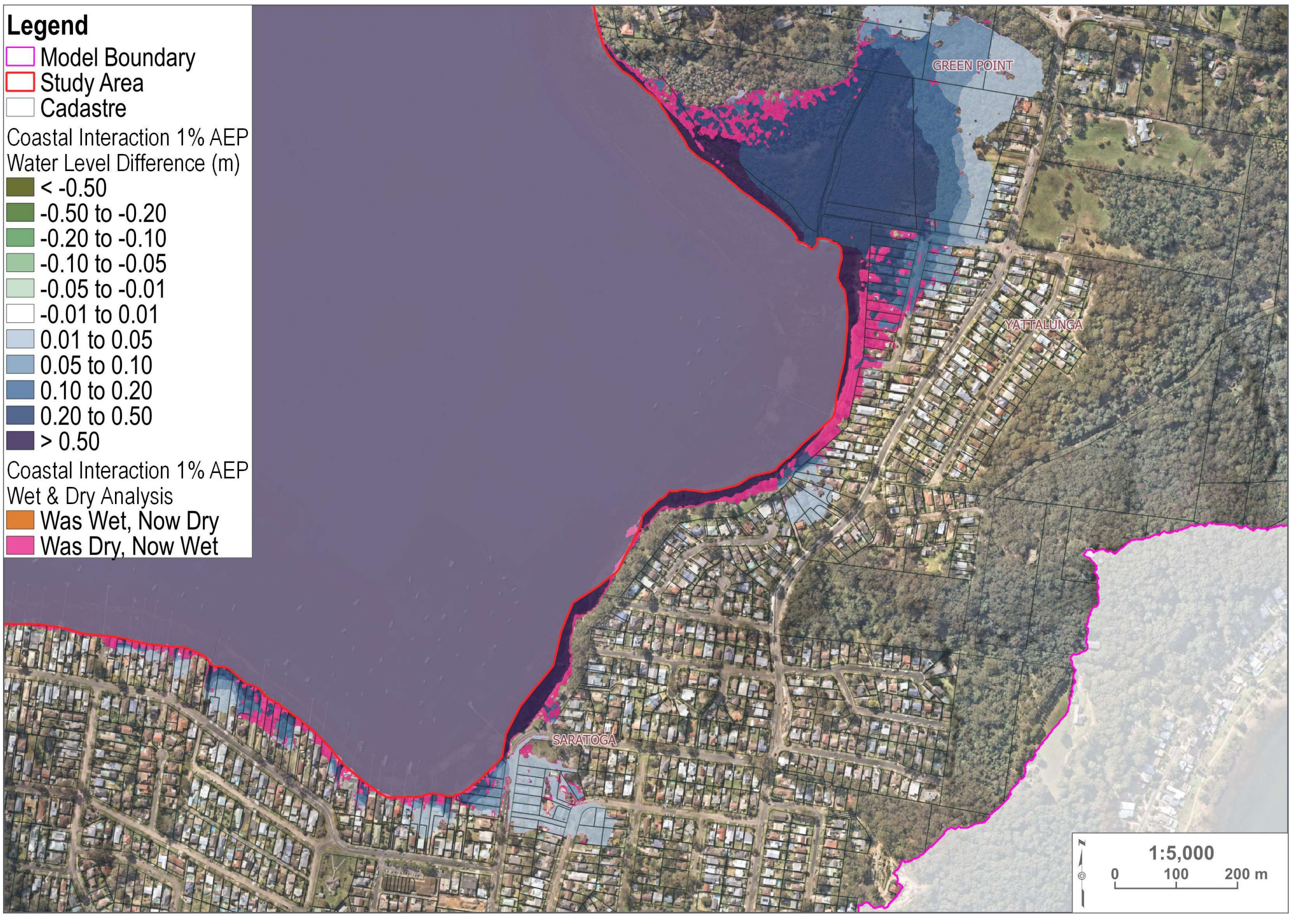


Figure 8-9 Coastal Interaction Inundation due to Storm Surge Event

8.7 Climate Change

Climate change results (presented in **Appendix J**) indicate similar flood affection as the coastal interaction scenarios. Increases in water levels are observed throughout the catchment.

Properties in the Tascott catchment are severely affected by climate change affects. The increased rainfall intensities result in higher depths upstream of the railway embankment causing increased flood levels by around 0.3m in the area by 2090. Existing culverts within the area are impacted by even higher backwater effects which results in poor conveyance of flows. Brisbane Water Drive experiences increased inundation and waterfront properties experience flooding due to the rising sea levels.

Avoca Drive and Davistown Road are major roads for access and traffic in the Green Point catchment. Both roads are impacted by climate change at several locations which results in increased inundation on the roads. Culverts underneath road embankments are unable to handle the increased flows. These culverts could potentially be upsized in order to convey more runoff away from overland areas.

A number of isolated properties are located by the waterfront along Marloo Road. Primary access to these properties is via Lara Street which is a low lying road starting under Spike Miligan Bridge in Parks Bay. Rising sea levels and floodwaters pose a risk to these properties and road access for evacuation.

8.8 Sensitivity Analysis

8.8.1 Buildings

Changing the building representation to blocked footprints results in floodwaters being trapped in more upstream areas of the flow paths. Localised increases are noticed in areas with lots of housing such as Green Point and Saratoga. This generally leads to lowered flood depths for downstream properties up to 0.05m in the 1% AEP event. The Tascott and Point Clare region is more sensitive to building representation as several houses obstruct the main flow paths. Impacts are higher in the PMF event and flood levels are increased up to 0.2m onto roads. Results for 1% AEP design event are presented in **Appendix K 01.01.00 to 01.01.07** and PMF results are presented in **Appendix K 06.01.00 to 06.01.07**.

8.8.2 Blockage

Blockage analysis (results presented in **Appendix K 02.01.00 to 02.01.07**) shows increased levels around the estuary as floodwaters fail to enter the stormwater network. In residential areas, the increases are relatively minor up to 0.1m in the 1% AEP storm. Some areas are more susceptible to flooding due to blockage including:

- Roundabout at Avoca Drive and Sun Valley Road
- Woy Woy Road bridge over Woy Woy Creek
- Culverts under Brisbane Water Drive at Tascott (shown in **Figure 8-10**)

Blockage does not significantly impact the PMF results as the catchment is already heavily inundated and the downstream pipes are mostly running at full capacity. Results for 1% AEP design event are presented in **Appendix K 02.01.00 to 02.01.07** and PMF results are presented in **Appendix K 07.01.00 to 07.01.07**.

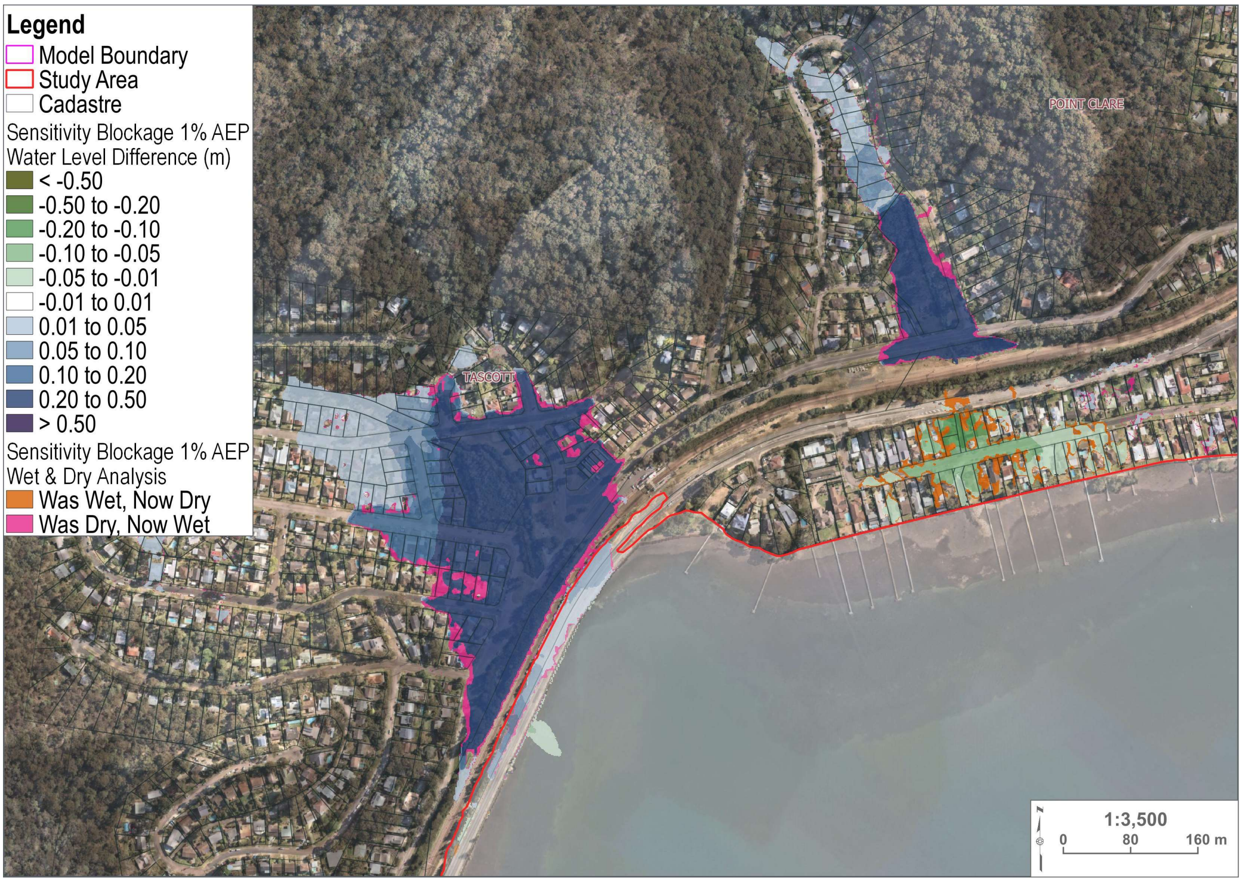


Figure 8-10 Blockage Sensitivity for Culverts in Tascott

8.8.3 Losses

Comparison of flood behaviour between the two losses shows no significant changes to flood levels. In the PMF, reductions of up to 0.01m are noticed along several flow paths. Primarily, both the 1% AEP and PMF are large storms that are not impacted as significantly by the initial and continuing losses. Larger differences in flood behaviour may be present in less intense storms. Results for 1% AEP design event are presented in **Appendix K 03.01.00 to 03.01.07** and PMF results are presented in **Appendix K 08.01.00 to 08.01.07**.

8.8.4 Manning's

Manning's parameters are significant in modifying the flow behaviour within the catchment. Results show that changing the Manning's parameters by 20% significantly changes flood levels within the catchment. Differences around ± 0.05m in the 1% AEP and ± 0.15m in the PMF are observed across all residential areas. Proportionally, a lowering of Manning's n causes minor reductions in peak water levels. However increasing the roughness results in substantial changes in flood levels and extent around the catchment.

Results for 1% AEP design event for roughness which shows +/-20% Manning's are presented in **Appendix K 04.01.00 to 05.01.07**. The PMF results for +/-20% Manning's are presented in **Appendix 09.01.00 to 10.01.07**.

8.9 ARR 1987 Comparison

The ARR 1987 IFDs indicate higher storm burst depths for shorter durations. The adopted Narara IFD has greater storm burst depths for higher durations. This is also seen in the hydraulic modelling. The upstream areas of the catchments are higher in the ARR 1987 case. As the floodwaters reach the downstream areas where critical durations reach 120 minutes, the Narara IFD provides higher flood levels. Reductions in the range of 0.1m are noticed around the study area in the 1% AEP event.

8.10 Levee Assessment

The levee assessment (see **Appendix M**) shows changes to flood behaviour of constructing levees while maintaining existing terrain characteristics behind them. In the existing scenario, a levee along the waterfront results in floodwaters from overland banking up behind the levee, effectively unable to drain into the estuary. This results in higher flood levels localised to the proposed levee locations as the existing drainage system fails to quickly discharge flows under the levees. Increases of up to 1m are observed around the catchment.

As flood levels rise in the 2050 and 2090 events, it is observed that the levees start protecting the waterfront properties by blocking the primary source of flooding. Overland flows still pose a problem, but it is expected that by raising the terrain footprint in the catchment over a number of years, these localised increases can be mitigated.

9 Consequences of Flooding on the Community

Following the prediction of flood behaviour using hydraulic modelling, the results were used to generate flood planning information. Consequences of flooding to the community in the catchment were evalauted based on the modelled flood behaviour and used to generate flood planning information.

9.1 Flood Planning Controls

9.1.1 Flood Planning Area

The 1% AEP flood results indicate properties as flood affected and are used to set flood planning levels. A freeboard or increase in rainfall is used to obtain a realistic extent of flood affectation as actual flood levels observed may differ to predicted design storms. Access roads throughout the Study Area are cut by flood inundation in events as frequent as the 5% AEP, which results in the region becoming fragmented. Access roads outside of the catchment area are also likely to be cut during flood events which will restrict the ability of emergency personnel to service the community.

These risks increase with flood severity. Unless the PMF is adopted as the FPL, there will be a residual flood risk within the community, even if all development is built at the FPL. The community should be helped to understand that adhering to flood development controls does not mean that they are free of flood risk.

For this catchment, due to the low lying flat terrain towards the estuary, several shallow flow regions were observed. It was determined that a flat increase in flood levels due to the addition of a freeboard would artificially widen the Flood Planning Area (FPA) to mark an unrealistic number of properties in flat areas. In scenarios like these, it is more suitable to apply an increase in rainfall such that the FPA is consistent in varying terrains.

Flood controls are applied based on if the property is impacted in the FPA or the PMF. Comparisons of proposed flood planning areas were made using the extreme flood events such as the 0.2% AEP, PMF and 1% AEP with 30% rainfall increase. Results indicate that the 1% AEP with 30% rainfall increase presents a realistic area and number of lots to be marked as flood affected. Similar flood behaviour was also observed in the adjacent Kincumber Overland Flood Study (MHL, 2015). It is proposed that the 1% AEP with 30% rainfall increase is adopted as the FPA for this catchment.

The puddle removal was set as 100m^2 for the design flood events. Sensitivity investigations were performed to see the impact of a 200 m^2 puddle filter on the number of encoded properties. Isolated areas with flood depths greater than 0.15m were observed within the catchment on several lots as a result of terrain data and steep cliff faces. The comparison of various extents on the number of lots affected in the 1% AEP and PMF event is summarised in **Table 9-1**.

Table 9-1 Comparison of Lots Tagged by Varying the FPA Extent

Method	Criteria	FPA	PMF
1	100m^2 Puddle Removal	3616	5810
2	100m^2 Removal with Depths Greater than 0.15m	4499	6213
3	200m^2 Puddle Removal	3131	5428
4	200m^2 Removal with Depths Greater than 0.15m	4110	6150

Results indicate that switching from the 100 m^2 to 200 m^2 for the puddle filter does not significantly reduce the number of tagged properties. Noting that the adjacent catchments adopt a filtering criteria of 100m^2 for the FPA, it is recommended that the puddle filtering criteria is not adjusted at this stage. The inclusion of areas where flood depths are greater than 0.15m significantly increases the number of tagged properties in both the FPA and PMF tagging. It is recommended that method 2 is adopted for this catchment. This approach provides a conservative estimate within the catchment. Detailed analysis can be performed as part of the Flood Risk Management Study and Plan to understand the proportion of site impacted and reducing the tagged properties if required. Flood Planning Area mapping is included in **Appendix N**.

9.1.2 Freeboard

The Flood Planning Level (FPL) for the majority of areas across New South Wales has been traditionally based on the 1% AEP flood level plus a freeboard. A freeboard above the estimated flood level for habitable floor levels is generally set between 0.3 m – 0.5m for residential properties and can vary for industrial and commercial properties.

A variety of factors are to be considered in determining an appropriate FPL. Most important is the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain. Consequently, different types of land use need to be accounted for in the setting of an FPL.

Freeboard within the FPA was determined by observing the change in flood levels due to the various model parameters such as climate change, coastal interaction and sensitivity assessment.

Freeboard mapping (See **Appendix N**) has been generalised across the catchment in order to communicate flood risks more clearly with the community. It was found that a large number of properties exhibited an increase in flood levels of less than 0.2m due to the modelling parameters. It is therefore recommended that these properties incorporate a lower freeboard level of 0.3m. Properties with higher variation are recommended to adopt a freeboard of 0.5m. Flood data for each lot has been provided to Council as “BW FPA Values.xlsx” and as a GIS layer. Furthermore, the freeboard mapping also identified that the 500mm freeboard is also required in the Coorumbine Creek and Green Point catchments as there are foreshore properties which are flood affected due to the 2090 Climate Change scenario and the proposed Levee Assessment (see **Section 8.10**). Some properties may require additional assessment in order to confirm the freeboard requirement through the incorporation of ground survey or proposed designs within the site footprint.

Higher flood levels at the waterfront properties may occur due to mainstream flooding from Narara Creek or storm surge events in the estuary. At locations where multiple sources of flood affectation is observed, the peak 1% AEP flood level should be used in determining the flood planning level.

9.2 Emergency Response

Flood modelling indicates that some roads access is cut in events starting from 5% AEP as summarised in **Table 8-2**.

The results demonstrate that evacuation of the floodplain using major roads is not a safe emergency management strategy in the case of flood. It is recommended that flood depth gauges are installed as signs on all major road crossings. Marking historic and design floods on the flood gauges would also provide additional information to the community and highlight the significant risk present:

- The ability of emergency services to respond to flooding in the region will be limited by the flooding of roads both to and within the Study Area;
- Flooding occurs over several hours, which also inhibits the ability of emergency services to provide assistance, as by the time they are able to access regions of the Study Area, the flood waters are likely to have receded; and
- The community will need to be flood aware as they will need to largely manage flood concerns themselves.

To assist in the planning and implementation of response strategies the State Emergency Service (SES) classifies communities according to their flood impact. Flood affected communities are those in which the normal functioning of services is altered either directly or indirectly because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. The classifications adopted by the SES (2007c) are:

- **Flood Islands.** These are inhabited or potentially habitable areas of high ground within a floodplain linked to the flood-free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. Flood islands can be further classified as:
  - High Flood Island - the flood island contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground; and
  - Low Flood Island - the flood island does not have enough flood-free land to cope with the number of people in the area or the island will eventually become inundated by floodwaters.
- **Trapped Perimeter Areas.** These would generally be inhabited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through flood prone land and

unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped Perimeter Areas are further classified according to their evacuation route:

  - High Trapped Perimeter - the area contains enough flood-free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground; and
  - Low Trapped Perimeter - the area does not have enough flood-free land to cope with the number of people in the area or the island will eventually become inundated by floodwaters.

- **Areas Able to be Evacuated.** These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated.
  - Areas with Overland Escape Route - access roads to flood free land cross lower lying flood prone land; and
  - Areas with Rising Road Access - access roads rise steadily uphill and away from the rising floodwaters.
- **Overland Refuge Areas**. These are location that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas.

The flood emergency response planning classifications in the 1% AEP and PMF events for the floodplain are mapped in **Appendix N**. It is predominantly classified as “High Trapped Perimeter Area” due to the blocking of access roads. The emergency response requirement is most likely evacuation to local refuge centres if the residents cannot take shelter in their property. Some potential evacuation centres are shown in **Figure 9-1**.

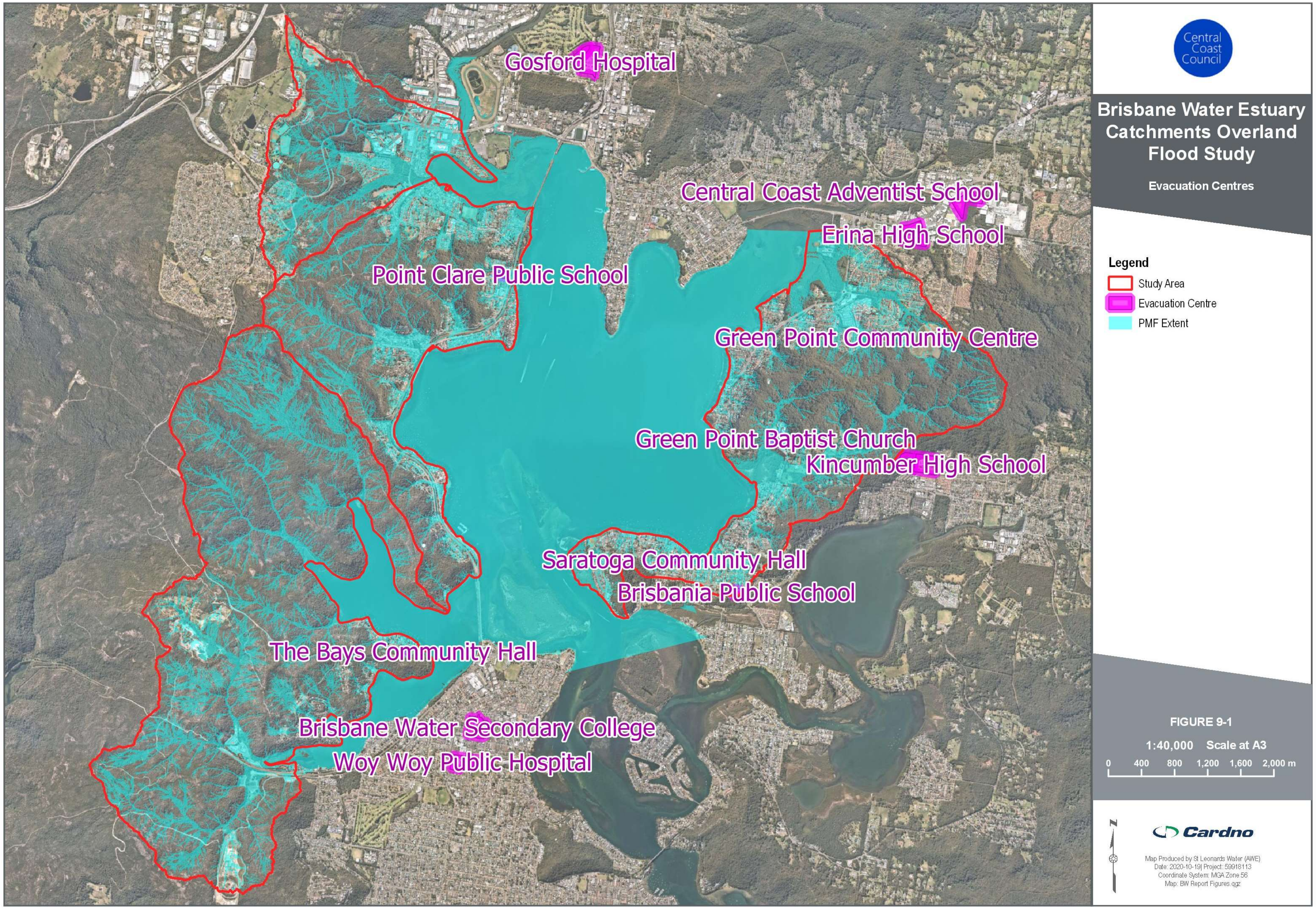


Figure 9-1 Evacuation Centres

9.3 Land Use Planning

The hydrological regime of the catchment can vary due to changes in land-use, particularly with an increase in the density of development. The removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels can be increased.

A potential impact on flooding can arise through the intensity of development on the floodplain, which may either remove flood storage or impact on the conveyance of flows. Controls established for precincts require that post-development flows are equal to or less than pre-development flows in order to reduce the risks of off-site impacts arising from the precinct development. It is important that available land be used in an appropriate, sustainable way, in order to meet the needs of both the growing population, as well as ecosystem health and services. **Table 9-2** shows the percentage of each land use zone that is covered in the 1% AEP and PMF flood extents in the four catchments.

Table 9-2 Proportional Flooding in Various Land Use Zones

Zoning Category	Green Point		Coorumbine Creek		Woy Woy Bay		Point Clare to Koolewong	
	1% AEP	**PMF**	**1% AEP**	**PMF**	**1% AEP**	**PMF**	**1% AEP**	**PMF**
Business Development	0%	0%	1%	3%	0%	0%	0%	0%
Deferred Matter	8%	15%	3%	5%	1%	3%	0%	2%
Environmental Conservation	0%	0%	0%	0%	1%	2%	0%	0%
Environmental Management	0%	0%	0%	1%	0%	0%	0%	0%
General Industrial	0%	0%	1%	3%	1%	1%	0%	0%
General Residential	0%	0%	1%	1%	0%	0%	0%	0%
Infrastructure	1%	2%	2%	4%	1%	1%	1%	3%
Local Centre	0%	0%	0%	0%	0%	0%	0%	0%
Low Density Residential	5%	13%	2%	7%	0%	1%	6%	15%
National Parks and Nature Reserves	0%	0%	2%	4%	6%	21%	3%	10%
Neighbourhood Centre	0%	0%	0%	0%	0%	0%	0%	0%
Primary Production	0%	0%	1%	2%	0%	0%	0%	0%
Public Recreation	3%	4%	2%	3%	0%	0%	2%	3%
Recreational Waterways	0%	0%	0%	1%	0%	0%	0%	0%
Rural Landscape	0%	0%	0%	0%	0%	0%	0%	0%
Special Activities	0%	0%	3%	11%	0%	1%	0%	0%
Total Flood Affected Area (%)	17%	35%	19%	45%	10%	30%	14%	34%
Total Flood Affected Area (km2)	1.54	3.14	0.72	1.73	1.48	4.39	0.95	2.39

Current guidance from the Australian Institute for Disaster Resilience indicate the use of Flood Planning Constraint Categorisation (FPCC) to guide the decision making process for future development. The classification is split into four criteria based on varying storm intensities in order to visualise the formation of flow paths. For this study, FPCC mapping was generated based on the following criteria:

1. FPCC 1 – 1% AEP floodway (flood conveyance) and flood storage, and 1% AEP H6 Hazard zones.
2. FPCC 2 – 1% AEP H5 Hazard zone and FPA (1% AEP with 30% Rainfall Increase) flood conveyance and FPA H6 Hazard
3. FPCC 3 – FPA Extent
4. FPCC 4 – PMF Extent

The classification of FPCC varies based on the type of flooding and landform data available. The above criteria was found to highlight the significant flow paths and risk areas in urbanised zones. Maps of FPCC are included in **Appendix N**.

10 Conclusion and Recommendations

The Brisbane Water Estuary Catchments Overland Flood Study provides benchmark flood information for the Coorumbine Creek, Point Care to Koolewong, Woy Woy Bay and Green Point catchments. Results of the study define flood behaviour in the Study Area and will assist in raising community awareness of flooding and flood risk in the area. The study will be used by Council and various stakeholders to inform flood planning and emergency management in the Study Area.

This report describes the project objectives; data collection and review; hydrology and hydraulic model setup, calibration and validation; model scenarios; design event model results, sensitivity analysis and climate change scenarios. It also provides guidance on the adoption of Flood Planning Levels and Emergency Response parameters for use in planning and by the NSW SES.

Flood modelling showed a good correlation to all events with respect to timing of catchment response and modelled flood peak levels and flows. It was also validated against photographic records provided by Council and the community through a community consultation survey.

The Study uses current industry standard methods and guidelines in flood estimation using Australian Rainfall and Runoff 2019 and a series of OEH DPIE floodplain management guidelines. The design event flood estimates were validated to a Flood Frequency Analysis of observed annual peak flood levels. The modelling approach, model setup, parameters and results and the study outcomes have been reviewed thoroughly.

Investigations undertaken as part of this process identified a number of issues within the floodplain; including but not limited estuarine flooding, the flooding of access roads, and the impact of increases in rainfall intensity due to climate change. To address these issues, a series of flood mitigation levees were identified and preliminary assessments were undertaken. These will be addressed further in future Floodplain Risk Management Study and Plan or subsequent studies. Should Council undertake a more detailed levee assessment (see **Section 7.6**), additional drainage may also be required to provide adequate conveyance through the levees. Construction of the levees would potentially be undertaken over several years and stages. In order to prevent offsite impacts over existing properties, it is recommended that flood impact assessments are undertaken with the latest terrain data to ensure that the flow behaviour is as expected.

Flood Emergency Response Planning Classification of Communities and Flood Planning Constraints Categories have been assessed for the catchment to inform Council and SES regarding land-use planning and emergency management planning in future stages.

The key recommendations based on the outcomes of this Flood Study are:

- Review Council’s Development Control Plan and planning controls to define the minimum floor level required for flood affected properties across the study area. Properties where increase in flood levels of less than 0.2m are observed, it is recommended that a lower freeboard level of 0.3m is adopted. Properties with higher variation in flood levels, it is recommended that a freeboard level of 0.5m is adopted. Furthermore, 0.5m freeboard is also recommended for the properties within the Coorumbine Creek and Green Point catchments as there are foreshore properties which are flood affected due to the 2090 Climate Change scenario and levee assessment. At locations where multiple sources of flood affectation is observed, the peak 1% AEP flood level should be used in determining the Flood Planning Level;
- Review Council’s Development Control Plan and planning controls for future land use planning and development based on the Flood Planning Constraint Categorisation. This categorisation highlights the significant flow paths and risk areas in the urbanised zones;
- Adopt the recent new method of hazard categorisation, developed by the revised ARR manual (Book 6: Flood Hydraulics, Section 7.2.7). This method classifies hazard based on depth and velocity, but utilises six categories from H1 (least hazard) to H6 (highest hazard) based on the stability of children, adults, the elderly, and vehicles in flood waters;
- Adapting to climate change and rising sea levels should be considered in development controls, design of mitigation options (such as levees), and setting minimum floor levels. It is recommended that further assessments are undertaken to identify that the recommended freeboards provide the required protection for climate change scenarios; and
- Undertake the next stage of the floodplain risk management process, which is the development of the Floodplain Risk Management Study and Plan. The study will help to determine potential flood mitigation

options as well as planning and emergency management measures considering social, economic and environmental factors. The plan will provide a program for implementation of mitigation and management options.

This Flood Study presents contemporary flood models and mapping for Council’s use in planning decisions and to form the basis for the future stages of floodplain risk management. This Study is suitable for adoption by Council.

11 References

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APPENDIX

A

DETAILED SURVEY

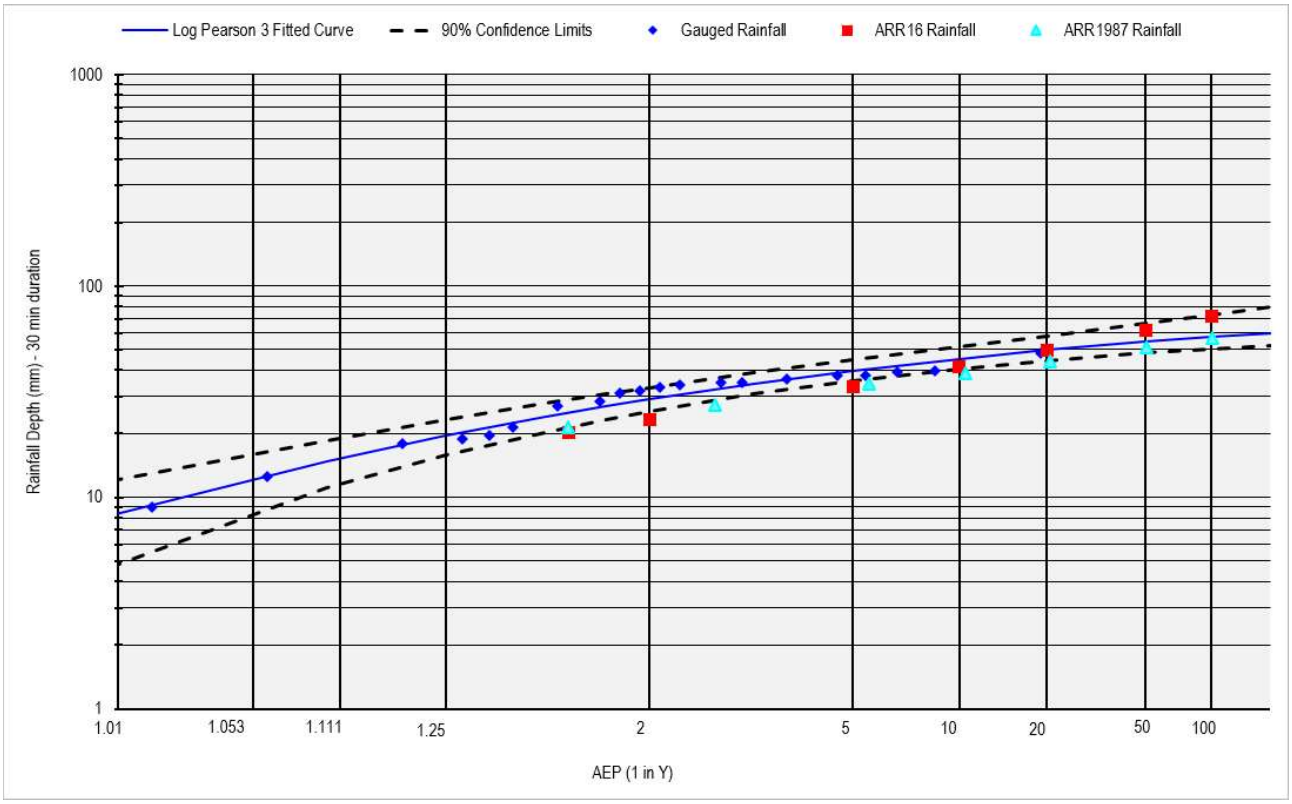
APPENDIX

B

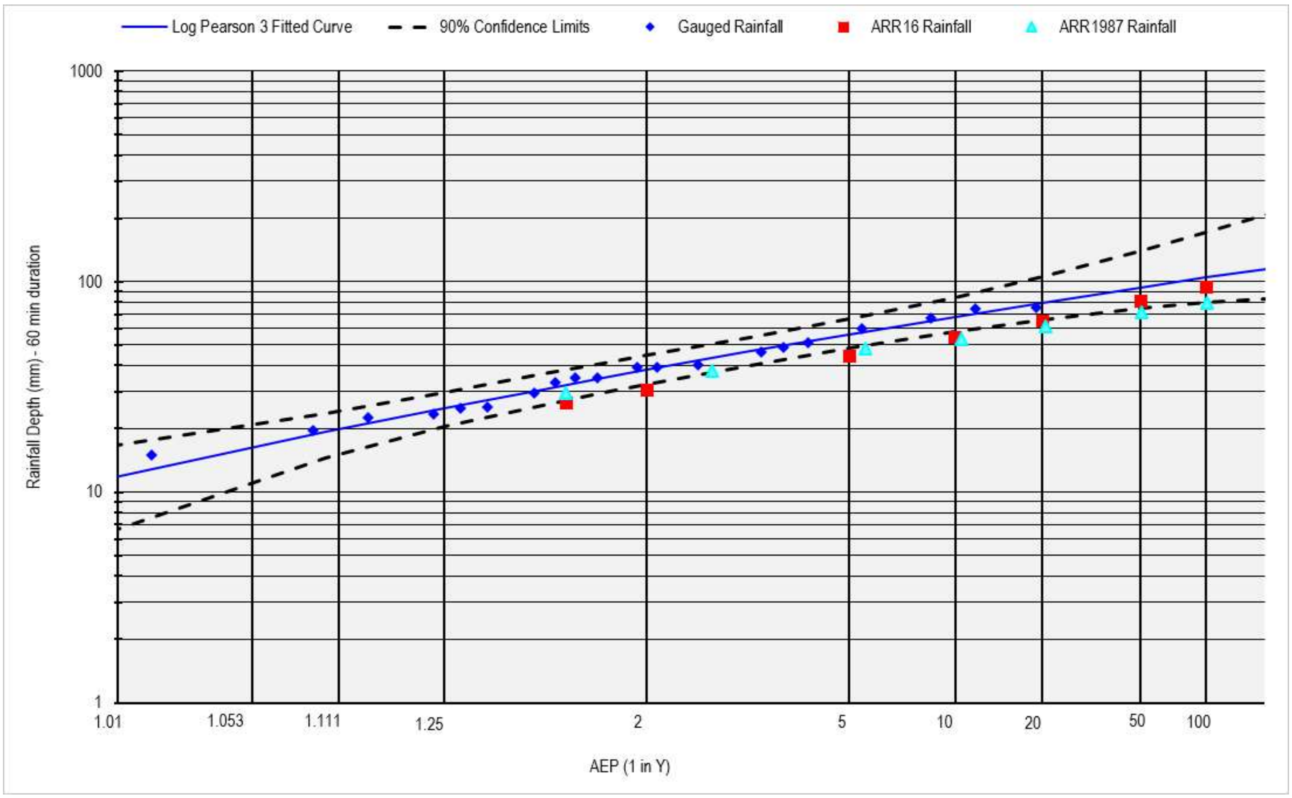
RAINFALL ANALYSIS

Summary of Annual Maximum Storm Burst Depths (mm) in Each Year

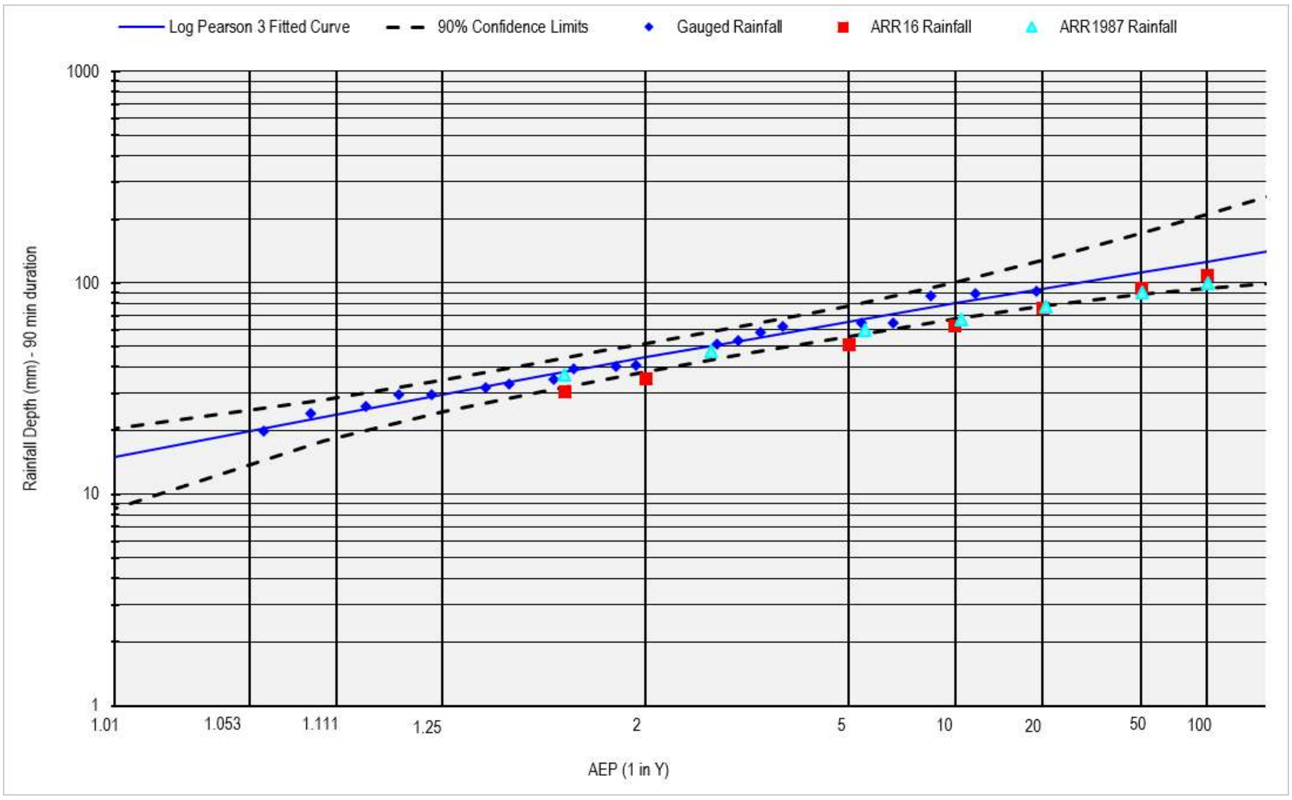
Year	30 mins	60 mins	90 mins	2 hr	3 hr	6 hr	9 hr	12 hr	18 hr	24 hr
1989	31	39	53.5	68	85	101.5	103	105	138.5	140.5
1990	27	33	40	52	72	111	143.5	167	223	294.5
1991	28.5	29.5	29.5	29.5	32	50.5	68	85.5	126.5	154
1992	39.5	75	91.5	112	129	154.5	212.5	245	274.5	317
1993	35	35	35	35	35	39	44.5	48	49.5	51.5
1994	37.5	67.5	86.5	115	121.5	126.5	127.5	130	142	146.5
1995	19	25.5	29.5	32	38.5	41	51	62	79	89.5
1996	19.5	23.5	32	40	57.5	93.5	112.5	122	144.5	153.5
1997	9	15	20	24	33	48.5	60	62.5	64.5	71.5
1998	36.5	46.5	58	66	72.5	76	95	116	129	133.5
1999	18	25	33	39	49.5	81	87.5	99	123	125
2000	12.5	19.5	24	25.5	29	56	79.5	92.5	110.5	125.5
2001	37.5	40	51.5	54.5	62.5	73	75.5	76	89	91.5
2002	48	74.5	89	94	95.5	95.5	97.5	109	109.5	114.5
2003	39	60	62	64	73	91.5	94	95.5	104	130
2004	21.5	22.5	26	31.5	38.5	52	58.5	66.5	85.5	106.5
2005	34	39	39	39.5	41	43.5	46.5	51	76.5	94
2006	35	51.5	64.5	69	74	79	86.5	86.5	87.5	90
2007	33	49	64.5	68.5	71.5	91.5	111	114.5	195	214.5
2008	32	35	40.5	42.5	47.5	48.5	55	69	90	98
2009	22.5	37.5	39.5	40.5	44	45	45	51	56.5	70
2010	52	62	63.5	63.5	64	64	64	64	64.5	69
2011	44.5	81.5	92	96	102.5	115.5	118	119	120	120
2012	28	40	47	57.5	64	80	94	115.5	138.5	150
2013	14.5	23	31.5	38	42.5	70	96.5	122.5	162	175.5
2014	34.5	40.5	42.5	45	46	52.5	52.5	52.5	52.5	52.5
2015	19	28.5	35	35.5	37	56	74.5	91	115.5	130
2016	35.5	54	62	74	79	79.5	82.5	98	130.5	165
2017	37	45.5	46	46	46	46.5	55.5	59	59	77
2018	13.5	16	18	22.5	32	46.5	58.5	67	87.5	96.5



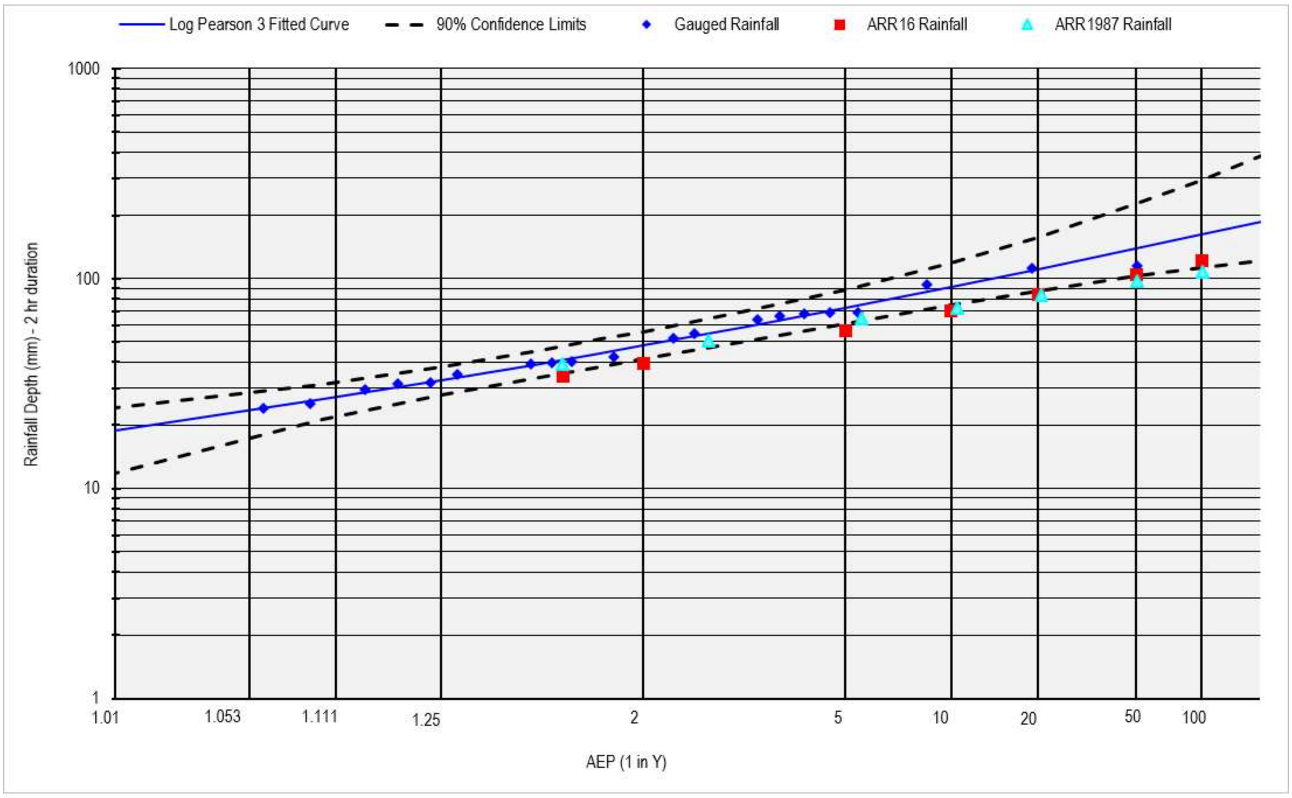
30 min Storm Burst Depth



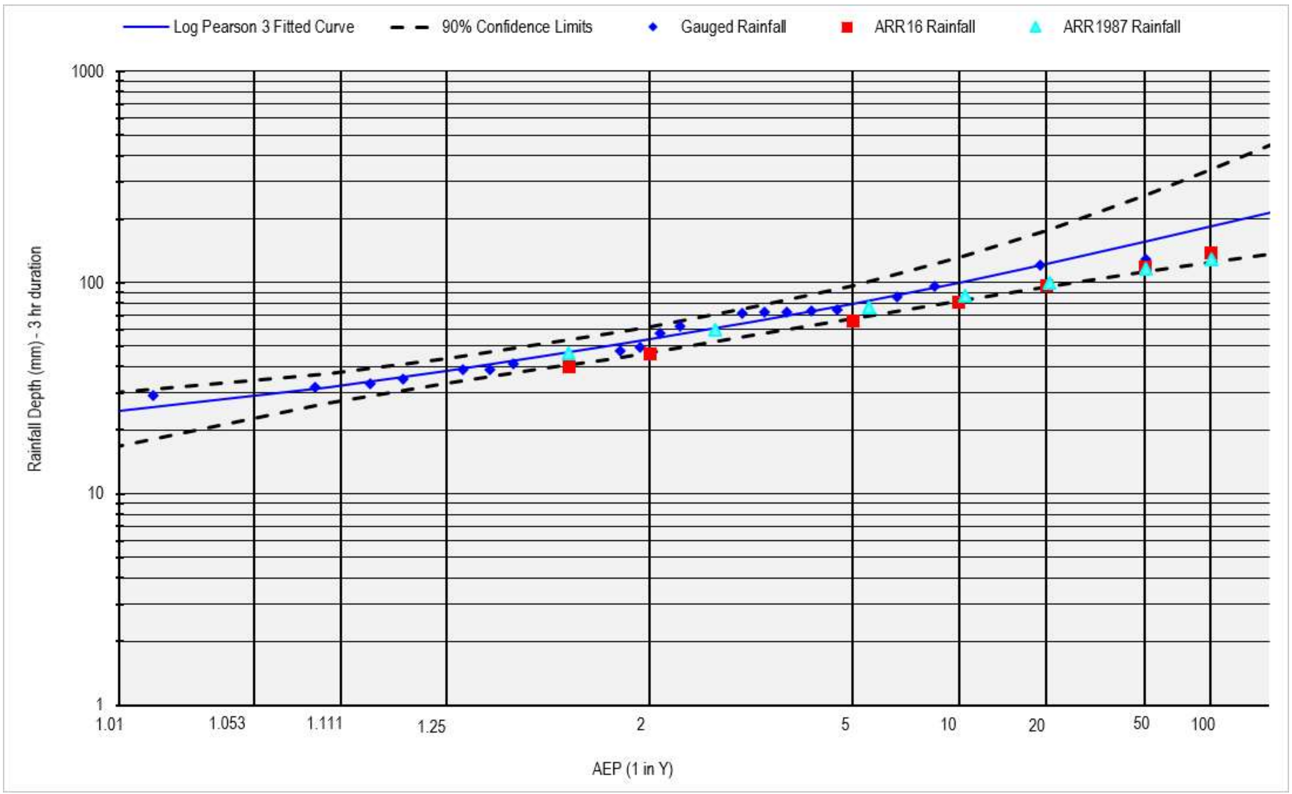
60 min Storm Burst Depth



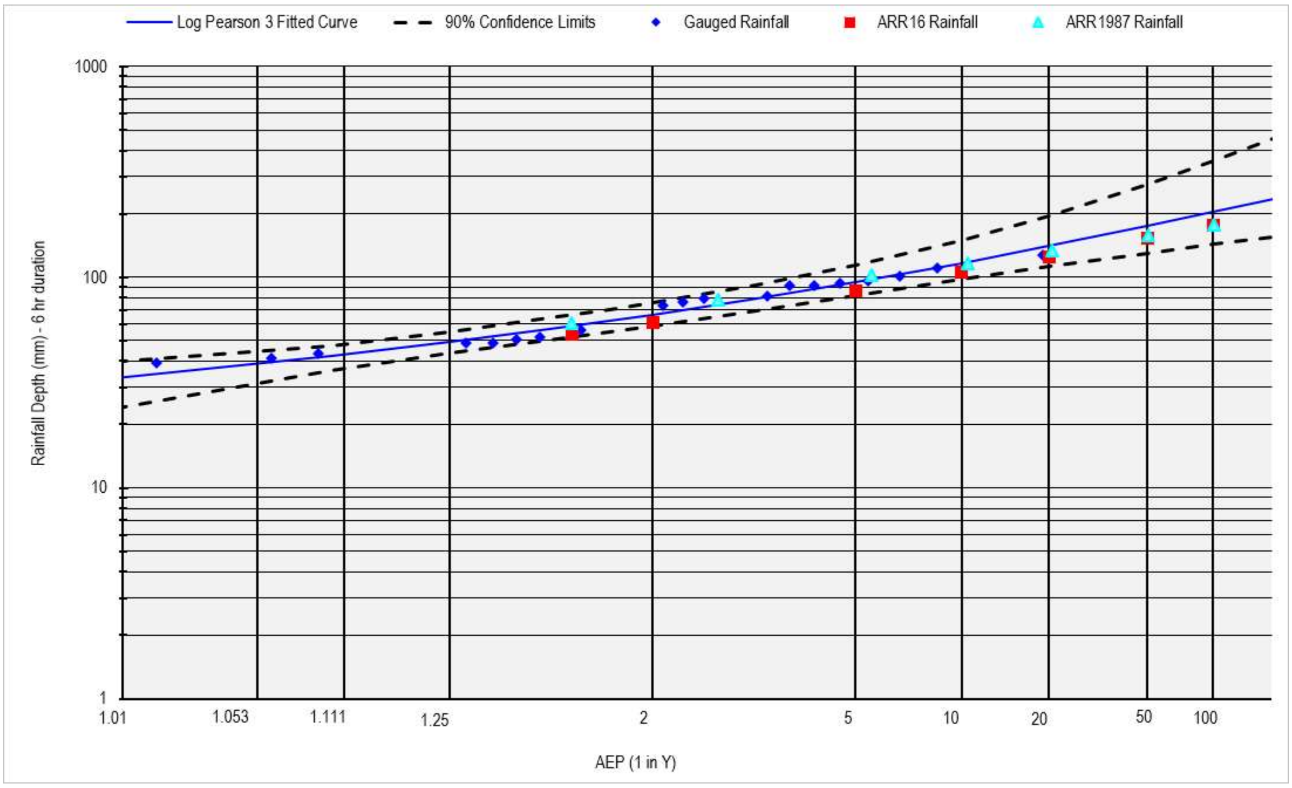
90 min Storm Burst Depth



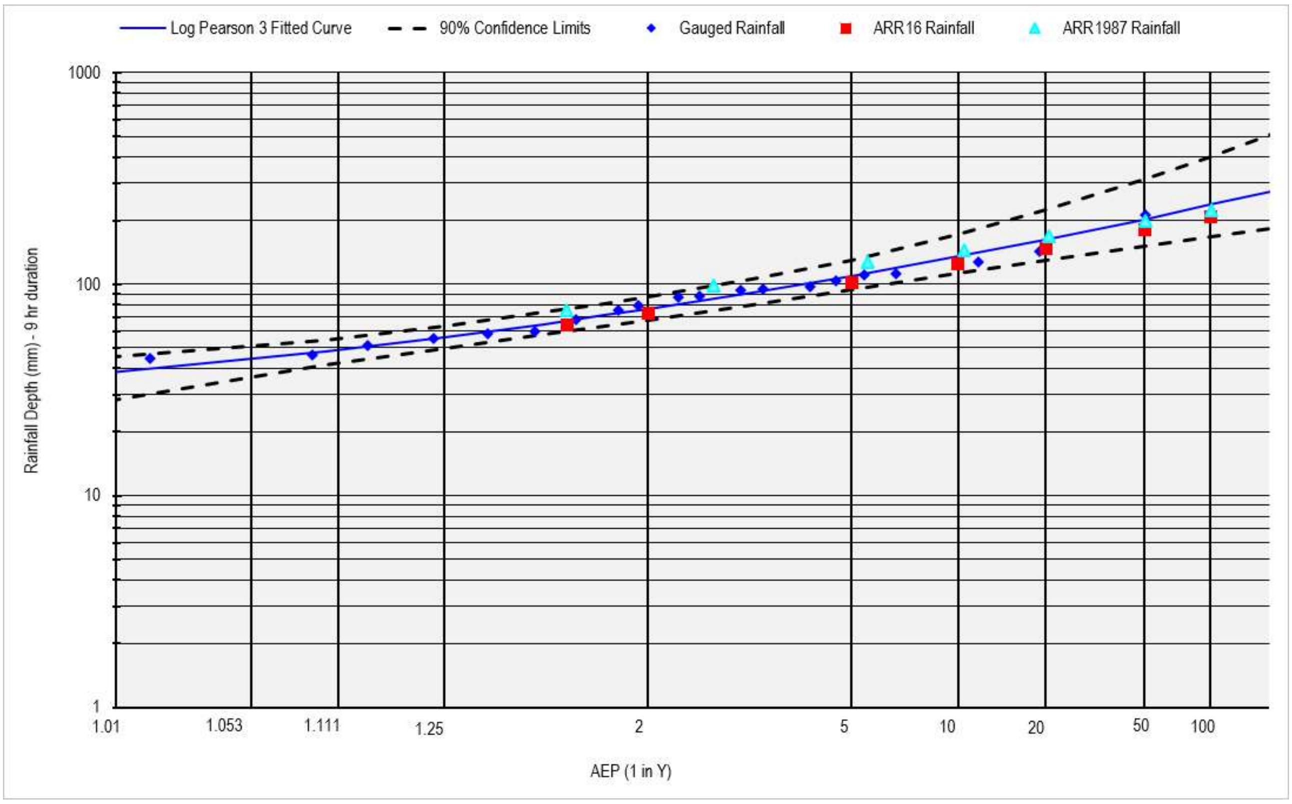
120 min Storm Burst Depth



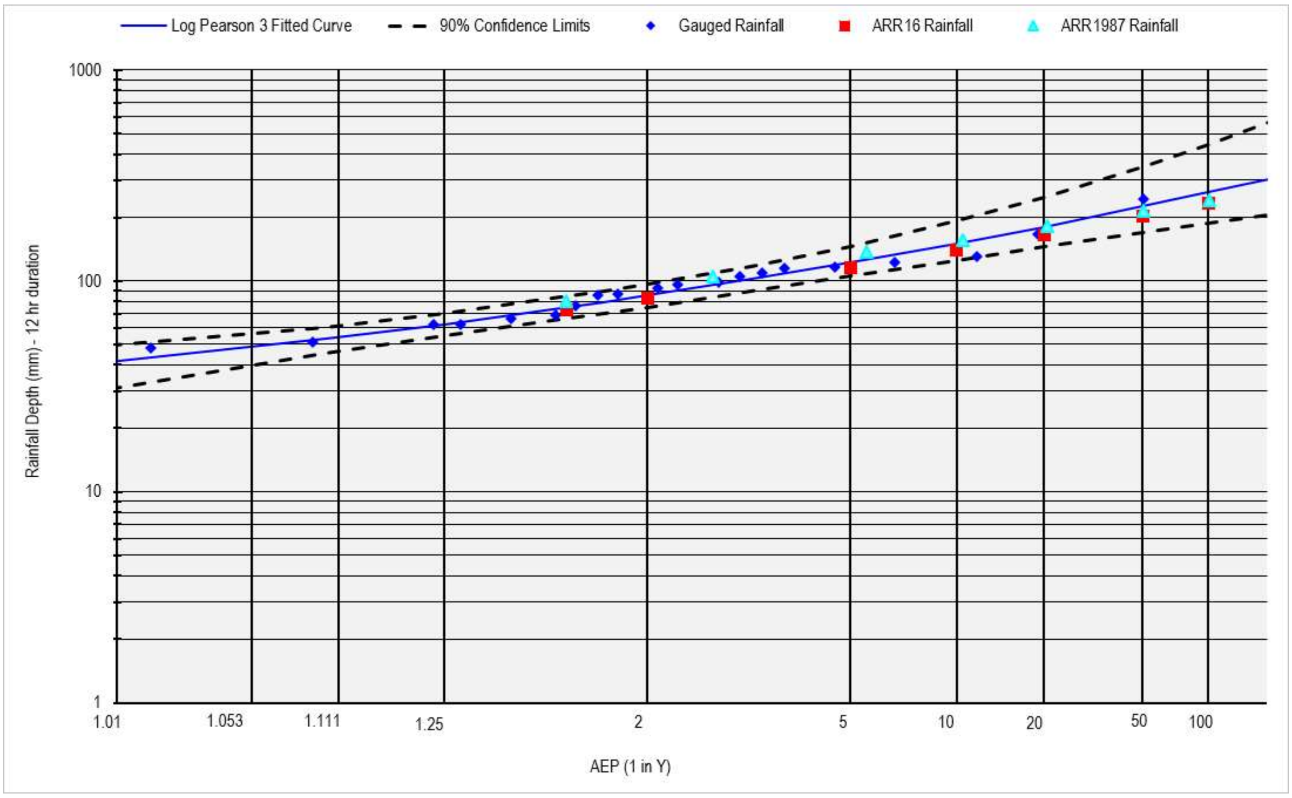
180 min Storm Burst Depth



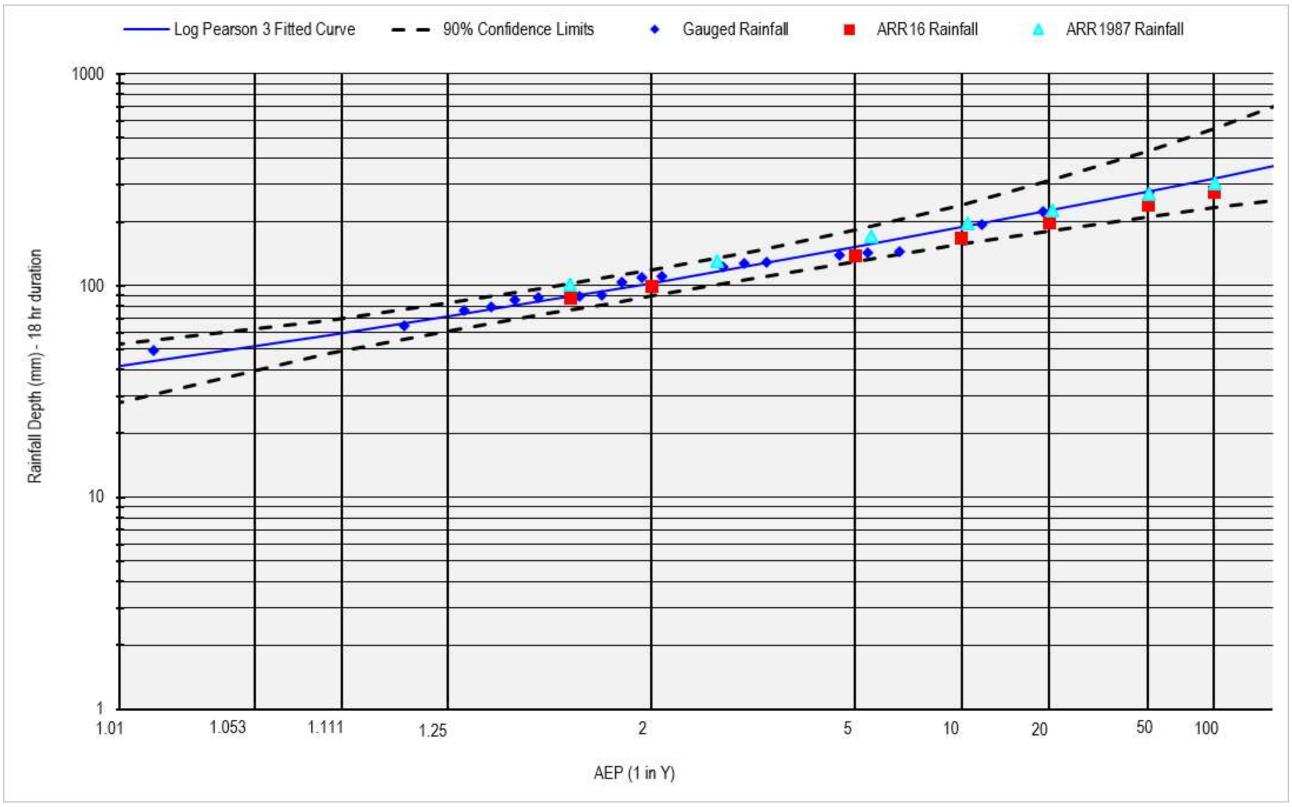
360 min Storm Burst Depth



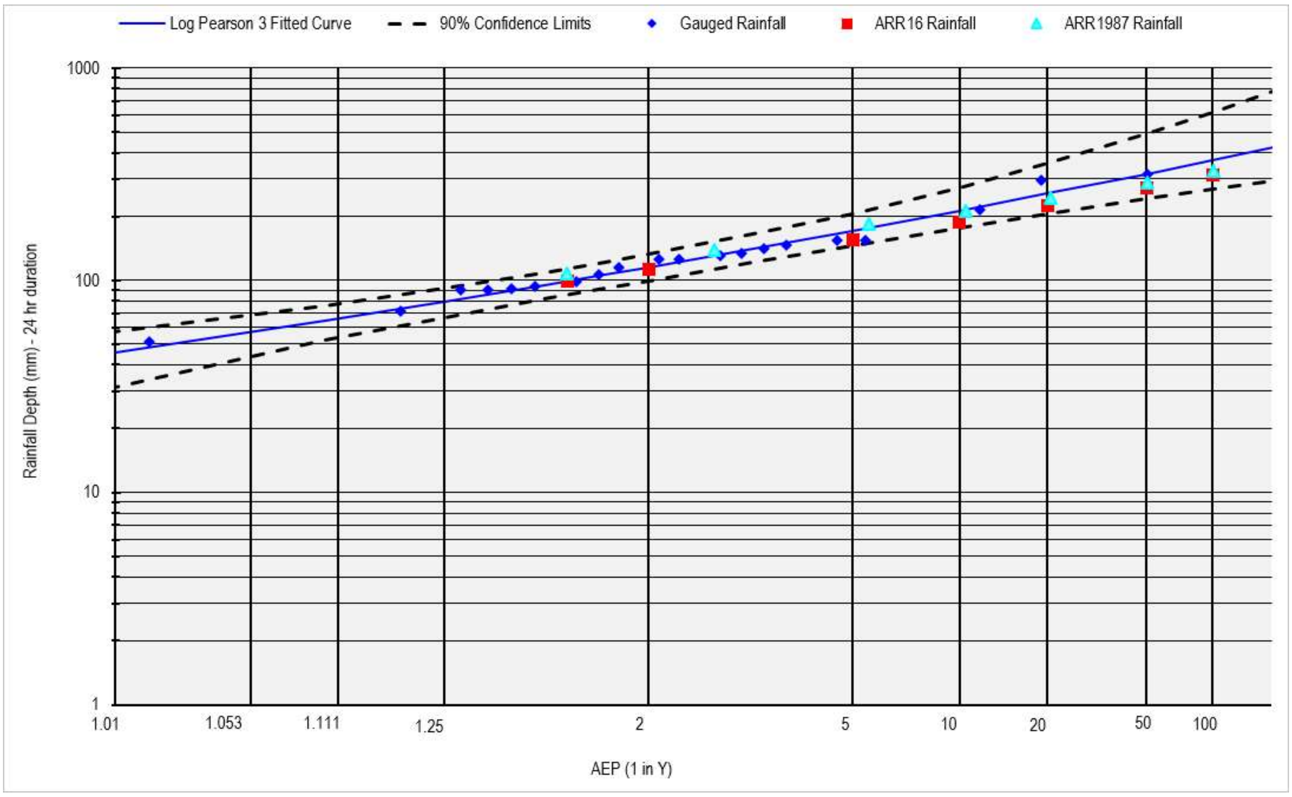
540 min Storm Burst Depth



720 min Storm Burst Depth



1080 min Storm Burst Depth



1440 min Storm Burst Depth

Comparison of Narrara, ARR20176 and ARR1987 Storm Burst Depths

Duration	AEP (1 in Y)	Expected parameter quantile	Monte Carlo 90% probability limits		ARR 2016 Rainfall Depth (mm)	ARR 2016 Rainfall within Confidence Limit	ARR 1987 Rainfall Depth (mm)	ARR87 Rainfall within Confidence Limit
			Lower Limit	**Upper Limit**				
30min	1.5	24.01	20.32	27.81	20.2	NO	21.50	YES
	2	29.08	25.47	33.12	23.2	NO	27.50	YES
	5	39.7	35.62	44.86	33.5	NO	34.65	NO
	10	45.29	40.68	51.69	41.3	YES	38.70	NO
	20	49.74	44.50	58.23	49.6	YES	44.15	NO
	50	54.46	48.20	66.81	61.7	YES	51.00	YES
	100	57.38	50.34	73.07	71.9	YES	56.5	YES
60min	1.5	30.78	25.99	36.31	26.4	YES	29.4	YES
	2	38.02	32.4	44.67	30.4	NO	37.7	YES
	5	56.19	48.16	66.42	44	NO	47.8	NO
	10	68.16	57.72	84.09	54.3	NO	53.5	NO
	20	79.48	66.03	106.1	65.3	NO	61.2	NO
	50	93.9	74.52	140.64	81.2	YES	71.2	NO
	100	104.58	79.58	171.62	94.5	YES	78.8	NO
90min	1.5	36.08	30.62	42.22	30.7	YES	36.75	YES
	2	44.26	37.93	51.74	35.3	NO	47.175	YES
	5	65.35	55.81	78.04	51	NO	60	YES
	10	79.72	67.23	100.82	62.9	NO	67.35	YES
	20	93.71	77.36	128.83	75.6	NO	77.1	NO
	50	112.09	88.08	170.99	93.8	YES	89.925	YES
	100	126.11	94.21	210.22	109	YES	99.6	YES
2hr	1.5	39.37	33.83	45.54	34.2	YES	39.2	YES
	2	48.05	41.33	56.02	39.3	NO	50.4	YES
	5	72.52	61.16	88.05	56.6	NO	64.4	YES
	10	91.01	74.81	118.6	69.7	NO	72.6	NO
	20	110.48	87.41	158.03	83.6	NO	83.2	NO
	50	138.37	102.73	226.68	104	YES	97.4	NO
	100	161.43	112.34	295.43	121	YES	108	NO
3hr	1.5	44.81	39.19	51.32	40	YES	46.2	YES
	2	53.66	46.65	62.09	45.8	NO	59.4	YES
	5	79.56	67.46	97.12	65.7	NO	76.5	YES
	10	100.02	82.2	131.32	80.6	NO	86.4	YES
	20	122.29	95.9	176.31	96.5	YES	99.3	YES
	50	155.44	113.23	258.04	119	YES	116.4	YES
	100	183.86	125.2	341.09	139	YES	129.3	YES

6hr	1.5	56.7	50.38	64.05	53.4	YES	60.6	YES
	2	66.61	58.85	75.76	60.8	YES	78.6	YES
	5	94.95	81.5	113.51	85.9	YES	102	YES
	10	116.8	97.54	149.94	105	YES	115.8	YES
	20	140.2	112.38	195.79	125	YES	134.4	YES
	50	174.42	130.01	274.78	153	YES	157.8	YES
	100	203.32	142.91	354.58	177	YES	176.4	YES
9hr	1.5	64.86	57.53	73.36	63.9	YES	75.645	YES
	2	76.28	67.22	86.84	72.5	YES	98.1	YES
	5	109.18	93.64	130.45	102	YES	127.8	YES
	10	134.75	112.47	170.97	124	YES	145.35	YES
	20	162.31	129.99	224.3	147	YES	168.75	YES
	50	202.86	151.96	311.81	180	YES	198.9	YES
	100	237.3	168.07	399.42	207	YES	222.3	YES
12hr	1.5	72.16	63.82	81.48	72.6	YES	80.52	YES
	2	85.1	75.06	96.92	82.4	YES	104.4	YES
	5	122.03	105.16	145.56	115	YES	136.8	YES
	10	150.44	125.38	191.85	140	YES	156	YES
	20	180.82	145.16	249.97	165	YES	181.2	YES
	50	225.17	170.11	348.4	202	YES	214.8	YES
	100	262.54	188.25	445.03	233	YES	240	YES
18hr	1.5	85.19	73.57	97.74	87	YES	100.71	YES
	2	102.97	89.03	118.79	98.6	YES	130.68	YES
	5	151.95	129.81	182.86	138	YES	171.72	YES
	10	188.09	156.46	240.99	167	YES	196.11	YES
	20	225.52	181.23	313.41	197	YES	227.7	YES
	50	278.22	211.91	434.12	241	YES	270	YES
	100	321.12	232.61	554.29	276	YES	302.4	YES
24hr	1.5	94.48	81.28	108.51	98.5	YES	107.52	YES
	2	114.66	99.29	132.29	112	YES	139.68	YES
	5	170.71	145.35	206.73	156	YES	184.32	YES
	10	212.43	176.22	272.54	189	YES	210.96	YES
	20	255.9	205.19	354.43	224	YES	244.8	YES
	50	317.47	242.2	489.6	273	YES	290.4	YES
	100	367.88	268.91	620.24	312	YES	326.4	YES

APPENDIX

C

COMMUNITY CONSULTATION

APPENDIX

D

HISTORICAL STORM RESULTS

Figure	Scenario	Title
D.0.0.0	Overall	Figure Inset Locations
D.1.1.0	Historical Storms	March 2002 Depth
D.1.1.1	Historical Storms	March 2002 Depth
D.1.1.2	Historical Storms	March 2002 Depth
D.1.1.3	Historical Storms	March 2002 Depth
D.1.1.4	Historical Storms	March 2002 Depth
D.1.1.5	Historical Storms	March 2002 Depth
D.1.1.6	Historical Storms	March 2002 Depth
D.1.1.7	Historical Storms	March 2002 Depth
D.2.1.0	Historical Storms	March 2014 Depth
D.2.1.1	Historical Storms	March 2014 Depth
D.2.1.2	Historical Storms	March 2014 Depth
D.2.1.3	Historical Storms	March 2014 Depth
D.2.1.4	Historical Storms	March 2014 Depth
D.2.1.5	Historical Storms	March 2014 Depth
D.2.1.6	Historical Storms	March 2014 Depth
D.2.1.7	Historical Storms	March 2014 Depth
D.3.1.0	Historical Storms	April 2015 Depth
D.3.1.1	Historical Storms	April 2015 Depth
D.3.1.2	Historical Storms	April 2015 Depth
D.3.1.3	Historical Storms	April 2015 Depth
D.3.1.4	Historical Storms	April 2015 Depth
D.3.1.5	Historical Storms	April 2015 Depth
D.3.1.6	Historical Storms	April 2015 Depth
D.3.1.7	Historical Storms	April 2015 Depth
D.4.1.0	Historical Storms	March 2016 Depth
D.4.1.1	Historical Storms	March 2016 Depth
D.4.1.2	Historical Storms	March 2016 Depth
D.4.1.3	Historical Storms	March 2016 Depth
D.4.1.4	Historical Storms	March 2016 Depth
D.4.1.5	Historical Storms	March 2016 Depth
D.4.1.6	Historical Storms	March 2016 Depth
D.4.1.7	Historical Storms	March 2016 Depth

APPENDIX

E

CRITICAL DURATION BOX PLOTS

APPENDIX

F

DESIGN FLOOD BEHAVIOUR MAPS

Figure	Scenario	Title
F.0.0.0	Overall	Figure Inset Locations
F.1.1.0	Design	50% AEP Depth
F.1.1.1	Design	50% AEP Depth
F.1.1.2	Design	50% AEP Depth
F.1.1.3	Design	50% AEP Depth
F.1.1.4	Design	50% AEP Depth
F.1.1.5	Design	50% AEP Depth
F.1.1.6	Design	50% AEP Depth
F.1.1.7	Design	50% AEP Depth
F.1.2.0	Design	50% AEP Water Level
F.1.2.1	Design	50% AEP Water Level
F.1.2.2	Design	50% AEP Water Level
F.1.2.3	Design	50% AEP Water Level
F.1.2.4	Design	50% AEP Water Level
F.1.2.5	Design	50% AEP Water Level
F.1.2.6	Design	50% AEP Water Level
F.1.2.7	Design	50% AEP Water Level
F.1.3.1	Design	50% AEP Velocity
F.1.3.2	Design	50% AEP Velocity
F.1.3.3	Design	50% AEP Velocity
F.1.3.4	Design	50% AEP Velocity
F.1.3.5	Design	50% AEP Velocity
F.1.3.6	Design	50% AEP Velocity
F.1.3.7	Design	50% AEP Velocity
F.2.1.0	Design	20% AEP Depth
F.2.1.1	Design	20% AEP Depth
F.2.1.2	Design	20% AEP Depth
F.2.1.3	Design	20% AEP Depth
F.2.1.4	Design	20% AEP Depth
F.2.1.5	Design	20% AEP Depth
F.2.1.6	Design	20% AEP Depth
F.2.1.7	Design	20% AEP Depth
F.2.2.0	Design	20% AEP Water Level
F.2.2.1	Design	20% AEP Water Level
F.2.2.2	Design	20% AEP Water Level
F.2.2.3	Design	20% AEP Water Level
F.2.2.4	Design	20% AEP Water Level
F.2.2.5	Design	20% AEP Water Level
F.2.2.6	Design	20% AEP Water Level
F.2.2.7	Design	20% AEP Water Level
F.2.3.1	Design	20% AEP Velocity

F.2.3.2	Design	20% AEP Velocity
F.2.3.3	Design	20% AEP Velocity
F.2.3.4	Design	20% AEP Velocity
F.2.3.5	Design	20% AEP Velocity
F.2.3.6	Design	20% AEP Velocity
F.2.3.7	Design	20% AEP Velocity
F.3.1.0	Design	10% AEP Depth
F.3.1.1	Design	10% AEP Depth
F.3.1.2	Design	10% AEP Depth
F.3.1.3	Design	10% AEP Depth
F.3.1.4	Design	10% AEP Depth
F.3.1.5	Design	10% AEP Depth
F.3.1.6	Design	10% AEP Depth
F.3.1.7	Design	10% AEP Depth
F.3.2.0	Design	10% AEP Water Level
F.3.2.1	Design	10% AEP Water Level
F.3.2.2	Design	10% AEP Water Level
F.3.2.3	Design	10% AEP Water Level
F.3.2.4	Design	10% AEP Water Level
F.3.2.5	Design	10% AEP Water Level
F.3.2.6	Design	10% AEP Water Level
F.3.2.7	Design	10% AEP Water Level
F.3.3.1	Design	10% AEP Velocity
F.3.3.2	Design	10% AEP Velocity
F.3.3.3	Design	10% AEP Velocity
F.3.3.4	Design	10% AEP Velocity
F.3.3.5	Design	10% AEP Velocity
F.3.3.6	Design	10% AEP Velocity
F.3.3.7	Design	10% AEP Velocity
F.4.1.0	Design	5% AEP Depth
F.4.1.1	Design	5% AEP Depth
F.4.1.2	Design	5% AEP Depth
F.4.1.3	Design	5% AEP Depth
F.4.1.4	Design	5% AEP Depth
F.4.1.5	Design	5% AEP Depth
F.4.1.6	Design	5% AEP Depth
F.4.1.7	Design	5% AEP Depth
F.4.2.0	Design	5% AEP Water Level
F.4.2.1	Design	5% AEP Water Level
F.4.2.2	Design	5% AEP Water Level
F.4.2.3	Design	5% AEP Water Level
F.4.2.4	Design	5% AEP Water Level

F.4.2.5	Design	5% AEP Water Level
F.4.2.6	Design	5% AEP Water Level
F.4.2.7	Design	5% AEP Water Level
F.4.3.1	Design	5% AEP Velocity
F.4.3.2	Design	5% AEP Velocity
F.4.3.3	Design	5% AEP Velocity
F.4.3.4	Design	5% AEP Velocity
F.4.3.5	Design	5% AEP Velocity
F.4.3.6	Design	5% AEP Velocity
F.4.3.7	Design	5% AEP Velocity
F.5.1.0	Design	2% AEP Depth
F.5.1.1	Design	2% AEP Depth
F.5.1.2	Design	2% AEP Depth
F.5.1.3	Design	2% AEP Depth
F.5.1.4	Design	2% AEP Depth
F.5.1.5	Design	2% AEP Depth
F.5.1.6	Design	2% AEP Depth
F.5.1.7	Design	2% AEP Depth
F.5.2.0	Design	2% AEP Water Level
F.5.2.1	Design	2% AEP Water Level
F.5.2.2	Design	2% AEP Water Level
F.5.2.3	Design	2% AEP Water Level
F.5.2.4	Design	2% AEP Water Level
F.5.2.5	Design	2% AEP Water Level
F.5.2.6	Design	2% AEP Water Level
F.5.2.7	Design	2% AEP Water Level
F.5.3.1	Design	2% AEP Velocity
F.5.3.2	Design	2% AEP Velocity
F.5.3.3	Design	2% AEP Velocity
F.5.3.4	Design	2% AEP Velocity
F.5.3.5	Design	2% AEP Velocity
F.5.3.6	Design	2% AEP Velocity
F.5.3.7	Design	2% AEP Velocity
F.6.1.0	Design	1% AEP Depth
F.6.1.1	Design	1% AEP Depth
F.6.1.2	Design	1% AEP Depth
F.6.1.3	Design	1% AEP Depth
F.6.1.4	Design	1% AEP Depth
F.6.1.5	Design	1% AEP Depth
F.6.1.6	Design	1% AEP Depth
F.6.1.7	Design	1% AEP Depth
F.6.2.0	Design	1% AEP Water Level

F.6.2.1	Design	1% AEP Water Level
F.6.2.2	Design	1% AEP Water Level
F.6.2.3	Design	1% AEP Water Level
F.6.2.4	Design	1% AEP Water Level
F.6.2.5	Design	1% AEP Water Level
F.6.2.6	Design	1% AEP Water Level
F.6.2.7	Design	1% AEP Water Level
F.6.3.1	Design	1% AEP Velocity
F.6.3.2	Design	1% AEP Velocity
F.6.3.3	Design	1% AEP Velocity
F.6.3.4	Design	1% AEP Velocity
F.6.3.5	Design	1% AEP Velocity
F.6.3.6	Design	1% AEP Velocity
F.6.3.7	Design	1% AEP Velocity
F.7.1.0	Design	0.5% AEP Depth
F.7.1.1	Design	0.5% AEP Depth
F.7.1.2	Design	0.5% AEP Depth
F.7.1.3	Design	0.5% AEP Depth
F.7.1.4	Design	0.5% AEP Depth
F.7.1.5	Design	0.5% AEP Depth
F.7.1.6	Design	0.5% AEP Depth
F.7.1.7	Design	0.5% AEP Depth
F.7.2.0	Design	0.5% AEP Water Level
F.7.2.1	Design	0.5% AEP Water Level
F.7.2.2	Design	0.5% AEP Water Level
F.7.2.3	Design	0.5% AEP Water Level
F.7.2.4	Design	0.5% AEP Water Level
F.7.2.5	Design	0.5% AEP Water Level
F.7.2.6	Design	0.5% AEP Water Level
F.7.2.7	Design	0.5% AEP Water Level
F.7.3.1	Design	0.5% AEP Velocity
F.7.3.2	Design	0.5% AEP Velocity
F.7.3.3	Design	0.5% AEP Velocity
F.7.3.4	Design	0.5% AEP Velocity
F.7.3.5	Design	0.5% AEP Velocity
F.7.3.6	Design	0.5% AEP Velocity
F.7.3.7	Design	0.5% AEP Velocity
F.8.1.0	Design	0.2% AEP Depth
F.8.1.1	Design	0.2% AEP Depth
F.8.1.2	Design	0.2% AEP Depth
F.8.1.3	Design	0.2% AEP Depth
F.8.1.4	Design	0.2% AEP Depth

F.8.1.5	Design	0.2% AEP Depth
F.8.1.6	Design	0.2% AEP Depth
F.8.1.7	Design	0.2% AEP Depth
F.8.2.0	Design	0.2% AEP Water Level
F.8.2.1	Design	0.2% AEP Water Level
F.8.2.2	Design	0.2% AEP Water Level
F.8.2.3	Design	0.2% AEP Water Level
F.8.2.4	Design	0.2% AEP Water Level
F.8.2.5	Design	0.2% AEP Water Level
F.8.2.6	Design	0.2% AEP Water Level
F.8.2.7	Design	0.2% AEP Water Level
F.8.3.1	Design	0.2% AEP Velocity
F.8.3.2	Design	0.2% AEP Velocity
F.8.3.3	Design	0.2% AEP Velocity
F.8.3.4	Design	0.2% AEP Velocity
F.8.3.5	Design	0.2% AEP Velocity
F.8.3.6	Design	0.2% AEP Velocity
F.8.3.7	Design	0.2% AEP Velocity
F.9.1.0	Design	PMF Depth
F.9.1.1	Design	PMF Depth
F.9.1.2	Design	PMF Depth
F.9.1.3	Design	PMF Depth
F.9.1.4	Design	PMF Depth
F.9.1.5	Design	PMF Depth
F.9.1.6	Design	PMF Depth
F.9.1.7	Design	PMF Depth
F.9.2.0	Design	PMF Water Level
F.9.2.1	Design	PMF Water Level
F.9.2.2	Design	PMF Water Level
F.9.2.3	Design	PMF Water Level
F.9.2.4	Design	PMF Water Level
F.9.2.5	Design	PMF Water Level
F.9.2.6	Design	PMF Water Level
F.9.2.7	Design	PMF Water Level
F.9.3.1	Design	PMF Velocity
F.9.3.2	Design	PMF Velocity
F.9.3.3	Design	PMF Velocity
F.9.3.4	Design	PMF Velocity
F.9.3.5	Design	PMF Velocity
F.9.3.6	Design	PMF Velocity
F.9.3.7	Design	PMF Velocity

APPENDIX

G

DESIGN FLOOD RISK MAPS

Figure	Scenario	Title
G.0.0.0	Overall	Figure Inset Locations
G.1.4.0	Design	50% AEP Velocity Depth Product
G.1.4.1	Design	50% AEP Velocity Depth Product
G.1.4.2	Design	50% AEP Velocity Depth Product
G.1.4.3	Design	50% AEP Velocity Depth Product
G.1.4.4	Design	50% AEP Velocity Depth Product
G.1.4.5	Design	50% AEP Velocity Depth Product
G.1.4.6	Design	50% AEP Velocity Depth Product
G.1.4.7	Design	50% AEP Velocity Depth Product
G.1.5.0	Design	50% AEP Provisional Hazard
G.1.5.1	Design	50% AEP Provisional Hazard
G.1.5.2	Design	50% AEP Provisional Hazard
G.1.5.3	Design	50% AEP Provisional Hazard
G.1.5.4	Design	50% AEP Provisional Hazard
G.1.5.5	Design	50% AEP Provisional Hazard
G.1.5.6	Design	50% AEP Provisional Hazard
G.1.5.7	Design	50% AEP Provisional Hazard
G.1.6.0	Design	50% AEP General Hazard
G.1.6.1	Design	50% AEP General Hazard
G.1.6.2	Design	50% AEP General Hazard
G.1.6.3	Design	50% AEP General Hazard
G.1.6.4	Design	50% AEP General Hazard
G.1.6.5	Design	50% AEP General Hazard
G.1.6.6	Design	50% AEP General Hazard
G.1.6.7	Design	50% AEP General Hazard
G.1.7.0	Design	50% AEP Hydraulic Categories
G.1.7.1	Design	50% AEP Hydraulic Categories
G.1.7.2	Design	50% AEP Hydraulic Categories
G.1.7.3	Design	50% AEP Hydraulic Categories
G.1.7.4	Design	50% AEP Hydraulic Categories
G.1.7.5	Design	50% AEP Hydraulic Categories
G.1.7.6	Design	50% AEP Hydraulic Categories
G.1.7.7	Design	50% AEP Hydraulic Categories
G.2.4.0	Design	20% AEP Velocity Depth Product
G.2.4.1	Design	20% AEP Velocity Depth Product
G.2.4.2	Design	20% AEP Velocity Depth Product
G.2.4.3	Design	20% AEP Velocity Depth Product
G.2.4.4	Design	20% AEP Velocity Depth Product
G.2.4.5	Design	20% AEP Velocity Depth Product
G.2.4.6	Design	20% AEP Velocity Depth Product
G.2.4.7	Design	20% AEP Velocity Depth Product

G.2.5.0	Design	20% AEP Provisional Hazard
G.2.5.1	Design	20% AEP Provisional Hazard
G.2.5.2	Design	20% AEP Provisional Hazard
G.2.5.3	Design	20% AEP Provisional Hazard
G.2.5.4	Design	20% AEP Provisional Hazard
G.2.5.5	Design	20% AEP Provisional Hazard
G.2.5.6	Design	20% AEP Provisional Hazard
G.2.5.7	Design	20% AEP Provisional Hazard
G.2.6.0	Design	20% AEP General Hazard
G.2.6.1	Design	20% AEP General Hazard
G.2.6.2	Design	20% AEP General Hazard
G.2.6.3	Design	20% AEP General Hazard
G.2.6.4	Design	20% AEP General Hazard
G.2.6.5	Design	20% AEP General Hazard
G.2.6.6	Design	20% AEP General Hazard
G.2.6.7	Design	20% AEP General Hazard
G.2.7.0	Design	20% AEP Hydraulic Categories
G.2.7.1	Design	20% AEP Hydraulic Categories
G.2.7.2	Design	20% AEP Hydraulic Categories
G.2.7.3	Design	20% AEP Hydraulic Categories
G.2.7.4	Design	20% AEP Hydraulic Categories
G.2.7.5	Design	20% AEP Hydraulic Categories
G.2.7.6	Design	20% AEP Hydraulic Categories
G.2.7.7	Design	20% AEP Hydraulic Categories
G.3.4.0	Design	10% AEP Velocity Depth Product
G.3.4.1	Design	10% AEP Velocity Depth Product
G.3.4.2	Design	10% AEP Velocity Depth Product
G.3.4.3	Design	10% AEP Velocity Depth Product
G.3.4.4	Design	10% AEP Velocity Depth Product
G.3.4.5	Design	10% AEP Velocity Depth Product
G.3.4.6	Design	10% AEP Velocity Depth Product
G.3.4.7	Design	10% AEP Velocity Depth Product
G.3.5.0	Design	10% AEP Provisional Hazard
G.3.5.1	Design	10% AEP Provisional Hazard
G.3.5.2	Design	10% AEP Provisional Hazard
G.3.5.3	Design	10% AEP Provisional Hazard
G.3.5.4	Design	10% AEP Provisional Hazard
G.3.5.5	Design	10% AEP Provisional Hazard
G.3.5.6	Design	10% AEP Provisional Hazard
G.3.5.7	Design	10% AEP Provisional Hazard
G.3.6.0	Design	10% AEP General Hazard
G.3.6.1	Design	10% AEP General Hazard

G.3.6.2	Design	10% AEP General Hazard
G.3.6.3	Design	10% AEP General Hazard
G.3.6.4	Design	10% AEP General Hazard
G.3.6.5	Design	10% AEP General Hazard
G.3.6.6	Design	10% AEP General Hazard
G.3.6.7	Design	10% AEP General Hazard
G.3.7.0	Design	10% AEP Hydraulic Categories
G.3.7.1	Design	10% AEP Hydraulic Categories
G.3.7.2	Design	10% AEP Hydraulic Categories
G.3.7.3	Design	10% AEP Hydraulic Categories
G.3.7.4	Design	10% AEP Hydraulic Categories
G.3.7.5	Design	10% AEP Hydraulic Categories
G.3.7.6	Design	10% AEP Hydraulic Categories
G.3.7.7	Design	10% AEP Hydraulic Categories
G.4.4.0	Design	5% AEP Velocity Depth Product
G.4.4.1	Design	5% AEP Velocity Depth Product
G.4.4.2	Design	5% AEP Velocity Depth Product
G.4.4.3	Design	5% AEP Velocity Depth Product
G.4.4.4	Design	5% AEP Velocity Depth Product
G.4.4.5	Design	5% AEP Velocity Depth Product
G.4.4.6	Design	5% AEP Velocity Depth Product
G.4.4.7	Design	5% AEP Velocity Depth Product
G.4.5.0	Design	5% AEP Provisional Hazard
G.4.5.1	Design	5% AEP Provisional Hazard
G.4.5.2	Design	5% AEP Provisional Hazard
G.4.5.3	Design	5% AEP Provisional Hazard
G.4.5.4	Design	5% AEP Provisional Hazard
G.4.5.5	Design	5% AEP Provisional Hazard
G.4.5.6	Design	5% AEP Provisional Hazard
G.4.5.7	Design	5% AEP Provisional Hazard
G.4.6.0	Design	5% AEP General Hazard
G.4.6.1	Design	5% AEP General Hazard
G.4.6.2	Design	5% AEP General Hazard
G.4.6.3	Design	5% AEP General Hazard
G.4.6.4	Design	5% AEP General Hazard
G.4.6.5	Design	5% AEP General Hazard
G.4.6.6	Design	5% AEP General Hazard
G.4.6.7	Design	5% AEP General Hazard
G.4.7.0	Design	5% AEP Hydraulic Categories
G.4.7.1	Design	5% AEP Hydraulic Categories
G.4.7.2	Design	5% AEP Hydraulic Categories
G.4.7.3	Design	5% AEP Hydraulic Categories

G.4.7.4	Design	5% AEP Hydraulic Categories
G.4.7.5	Design	5% AEP Hydraulic Categories
G.4.7.6	Design	5% AEP Hydraulic Categories
G.4.7.7	Design	5% AEP Hydraulic Categories
G.5.4.0	Design	2% AEP Velocity Depth Product
G.5.4.1	Design	2% AEP Velocity Depth Product
G.5.4.2	Design	2% AEP Velocity Depth Product
G.5.4.3	Design	2% AEP Velocity Depth Product
G.5.4.4	Design	2% AEP Velocity Depth Product
G.5.4.5	Design	2% AEP Velocity Depth Product
G.5.4.6	Design	2% AEP Velocity Depth Product
G.5.4.7	Design	2% AEP Velocity Depth Product
G.5.5.0	Design	2% AEP Provisional Hazard
G.5.5.1	Design	2% AEP Provisional Hazard
G.5.5.2	Design	2% AEP Provisional Hazard
G.5.5.3	Design	2% AEP Provisional Hazard
G.5.5.4	Design	2% AEP Provisional Hazard
G.5.5.5	Design	2% AEP Provisional Hazard
G.5.5.6	Design	2% AEP Provisional Hazard
G.5.5.7	Design	2% AEP Provisional Hazard
G.5.6.0	Design	2% AEP General Hazard
G.5.6.1	Design	2% AEP General Hazard
G.5.6.2	Design	2% AEP General Hazard
G.5.6.3	Design	2% AEP General Hazard
G.5.6.4	Design	2% AEP General Hazard
G.5.6.5	Design	2% AEP General Hazard
G.5.6.6	Design	2% AEP General Hazard
G.5.6.7	Design	2% AEP General Hazard
G.5.7.0	Design	2% AEP Hydraulic Categories
G.5.7.1	Design	2% AEP Hydraulic Categories
G.5.7.2	Design	2% AEP Hydraulic Categories
G.5.7.3	Design	2% AEP Hydraulic Categories
G.5.7.4	Design	2% AEP Hydraulic Categories
G.5.7.5	Design	2% AEP Hydraulic Categories
G.5.7.6	Design	2% AEP Hydraulic Categories
G.5.7.7	Design	2% AEP Hydraulic Categories
G.6.4.0	Design	1% AEP Velocity Depth Product
G.6.4.1	Design	1% AEP Velocity Depth Product
G.6.4.2	Design	1% AEP Velocity Depth Product
G.6.4.3	Design	1% AEP Velocity Depth Product
G.6.4.4	Design	1% AEP Velocity Depth Product
G.6.4.5	Design	1% AEP Velocity Depth Product

G.6.4.6	Design	1% AEP Velocity Depth Product
G.6.4.7	Design	1% AEP Velocity Depth Product
G.6.5.0	Design	1% AEP Provisional Hazard
G.6.5.1	Design	1% AEP Provisional Hazard
G.6.5.2	Design	1% AEP Provisional Hazard
G.6.5.3	Design	1% AEP Provisional Hazard
G.6.5.4	Design	1% AEP Provisional Hazard
G.6.5.5	Design	1% AEP Provisional Hazard
G.6.5.6	Design	1% AEP Provisional Hazard
G.6.5.7	Design	1% AEP Provisional Hazard
G.6.6.0	Design	1% AEP General Hazard
G.6.6.1	Design	1% AEP General Hazard
G.6.6.2	Design	1% AEP General Hazard
G.6.6.3	Design	1% AEP General Hazard
G.6.6.4	Design	1% AEP General Hazard
G.6.6.5	Design	1% AEP General Hazard
G.6.6.6	Design	1% AEP General Hazard
G.6.6.7	Design	1% AEP General Hazard
G.6.7.0	Design	1% AEP Hydraulic Categories
G.6.7.1	Design	1% AEP Hydraulic Categories
G.6.7.2	Design	1% AEP Hydraulic Categories
G.6.7.3	Design	1% AEP Hydraulic Categories
G.6.7.4	Design	1% AEP Hydraulic Categories
G.6.7.5	Design	1% AEP Hydraulic Categories
G.6.7.6	Design	1% AEP Hydraulic Categories
G.6.7.7	Design	1% AEP Hydraulic Categories
G.7.4.0	Design	0.5% AEP Velocity Depth Product
G.7.4.1	Design	0.5% AEP Velocity Depth Product
G.7.4.2	Design	0.5% AEP Velocity Depth Product
G.7.4.3	Design	0.5% AEP Velocity Depth Product
G.7.4.4	Design	0.5% AEP Velocity Depth Product
G.7.4.5	Design	0.5% AEP Velocity Depth Product
G.7.4.6	Design	0.5% AEP Velocity Depth Product
G.7.4.7	Design	0.5% AEP Velocity Depth Product
G.7.5.0	Design	0.5% AEP Provisional Hazard
G.7.5.1	Design	0.5% AEP Provisional Hazard
G.7.5.2	Design	0.5% AEP Provisional Hazard
G.7.5.3	Design	0.5% AEP Provisional Hazard
G.7.5.4	Design	0.5% AEP Provisional Hazard
G.7.5.5	Design	0.5% AEP Provisional Hazard
G.7.5.6	Design	0.5% AEP Provisional Hazard
G.7.5.7	Design	0.5% AEP Provisional Hazard

G.7.6.0	Design	0.5% AEP General Hazard
G.7.6.1	Design	0.5% AEP General Hazard
G.7.6.2	Design	0.5% AEP General Hazard
G.7.6.3	Design	0.5% AEP General Hazard
G.7.6.4	Design	0.5% AEP General Hazard
G.7.6.5	Design	0.5% AEP General Hazard
G.7.6.6	Design	0.5% AEP General Hazard
G.7.6.7	Design	0.5% AEP General Hazard
G.7.7.0	Design	0.5% AEP Hydraulic Categories
G.7.7.1	Design	0.5% AEP Hydraulic Categories
G.7.7.2	Design	0.5% AEP Hydraulic Categories
G.7.7.3	Design	0.5% AEP Hydraulic Categories
G.7.7.4	Design	0.5% AEP Hydraulic Categories
G.7.7.5	Design	0.5% AEP Hydraulic Categories
G.7.7.6	Design	0.5% AEP Hydraulic Categories
G.7.7.7	Design	0.5% AEP Hydraulic Categories
G.8.4.0	Design	0.2% AEP Velocity Depth Product
G.8.4.1	Design	0.2% AEP Velocity Depth Product
G.8.4.2	Design	0.2% AEP Velocity Depth Product
G.8.4.3	Design	0.2% AEP Velocity Depth Product
G.8.4.4	Design	0.2% AEP Velocity Depth Product
G.8.4.5	Design	0.2% AEP Velocity Depth Product
G.8.4.6	Design	0.2% AEP Velocity Depth Product
G.8.4.7	Design	0.2% AEP Velocity Depth Product
G.8.5.0	Design	0.2% AEP Provisional Hazard
G.8.5.1	Design	0.2% AEP Provisional Hazard
G.8.5.2	Design	0.2% AEP Provisional Hazard
G.8.5.3	Design	0.2% AEP Provisional Hazard
G.8.5.4	Design	0.2% AEP Provisional Hazard
G.8.5.5	Design	0.2% AEP Provisional Hazard
G.8.5.6	Design	0.2% AEP Provisional Hazard
G.8.5.7	Design	0.2% AEP Provisional Hazard
G.8.6.0	Design	0.2% AEP General Hazard
G.8.6.1	Design	0.2% AEP General Hazard
G.8.6.2	Design	0.2% AEP General Hazard
G.8.6.3	Design	0.2% AEP General Hazard
G.8.6.4	Design	0.2% AEP General Hazard
G.8.6.5	Design	0.2% AEP General Hazard
G.8.6.6	Design	0.2% AEP General Hazard
G.8.6.7	Design	0.2% AEP General Hazard
G.8.7.0	Design	0.2% AEP Hydraulic Categories
G.8.7.1	Design	0.2% AEP Hydraulic Categories

G.8.7.2	Design	0.2% AEP Hydraulic Categories
G.8.7.3	Design	0.2% AEP Hydraulic Categories
G.8.7.4	Design	0.2% AEP Hydraulic Categories
G.8.7.5	Design	0.2% AEP Hydraulic Categories
G.8.7.6	Design	0.2% AEP Hydraulic Categories
G.8.7.7	Design	0.2% AEP Hydraulic Categories
G.9.4.0	Design	PMF Velocity Depth Product
G.9.4.1	Design	PMF Velocity Depth Product
G.9.4.2	Design	PMF Velocity Depth Product
G.9.4.3	Design	PMF Velocity Depth Product
G.9.4.4	Design	PMF Velocity Depth Product
G.9.4.5	Design	PMF Velocity Depth Product
G.9.4.6	Design	PMF Velocity Depth Product
G.9.4.7	Design	PMF Velocity Depth Product
G.9.5.0	Design	PMF Provisional Hazard
G.9.5.1	Design	PMF Provisional Hazard
G.9.5.2	Design	PMF Provisional Hazard
G.9.5.3	Design	PMF Provisional Hazard
G.9.5.4	Design	PMF Provisional Hazard
G.9.5.5	Design	PMF Provisional Hazard
G.9.5.6	Design	PMF Provisional Hazard
G.9.5.7	Design	PMF Provisional Hazard
G.9.6.0	Design	PMF General Hazard
G.9.6.1	Design	PMF General Hazard
G.9.6.2	Design	PMF General Hazard
G.9.6.3	Design	PMF General Hazard
G.9.6.4	Design	PMF General Hazard
G.9.6.5	Design	PMF General Hazard
G.9.6.6	Design	PMF General Hazard
G.9.6.7	Design	PMF General Hazard
G.9.7.0	Design	PMF Hydraulic Categories
G.9.7.1	Design	PMF Hydraulic Categories
G.9.7.2	Design	PMF Hydraulic Categories
G.9.7.3	Design	PMF Hydraulic Categories
G.9.7.4	Design	PMF Hydraulic Categories
G.9.7.5	Design	PMF Hydraulic Categories
G.9.7.6	Design	PMF Hydraulic Categories
G.9.7.7	Design	PMF Hydraulic Categories

APPENDIX

H

DESIGN STORMWATER NETWORK CAPACITY MAPS

Figure	Scenario	Title
H.0.0.0	Overall	Figure Inset Locations
H.1.8.0	Design	50% AEP Stormwater Network Capacity
H.1.8.1	Design	50% AEP Stormwater Network Capacity
H.1.8.2	Design	50% AEP Stormwater Network Capacity
H.1.8.3	Design	50% AEP Stormwater Network Capacity
H.1.8.4	Design	50% AEP Stormwater Network Capacity
H.1.8.5	Design	50% AEP Stormwater Network Capacity
H.1.8.6	Design	50% AEP Stormwater Network Capacity
H.1.8.7	Design	50% AEP Stormwater Network Capacity
H.2.8.0	Design	20% AEP Stormwater Network Capacity
H.2.8.1	Design	20% AEP Stormwater Network Capacity
H.2.8.2	Design	20% AEP Stormwater Network Capacity
H.2.8.3	Design	20% AEP Stormwater Network Capacity
H.2.8.4	Design	20% AEP Stormwater Network Capacity
H.2.8.5	Design	20% AEP Stormwater Network Capacity
H.2.8.6	Design	20% AEP Stormwater Network Capacity
H.2.8.7	Design	20% AEP Stormwater Network Capacity
H.3.8.0	Design	10% AEP Stormwater Network Capacity
H.3.8.1	Design	10% AEP Stormwater Network Capacity
H.3.8.2	Design	10% AEP Stormwater Network Capacity
H.3.8.3	Design	10% AEP Stormwater Network Capacity
H.3.8.4	Design	10% AEP Stormwater Network Capacity
H.3.8.5	Design	10% AEP Stormwater Network Capacity
H.3.8.6	Design	10% AEP Stormwater Network Capacity
H.3.8.7	Design	10% AEP Stormwater Network Capacity
H.4.8.0	Design	5% AEP Stormwater Network Capacity
H.4.8.1	Design	5% AEP Stormwater Network Capacity
H.4.8.2	Design	5% AEP Stormwater Network Capacity
H.4.8.3	Design	5% AEP Stormwater Network Capacity
H.4.8.4	Design	5% AEP Stormwater Network Capacity
H.4.8.5	Design	5% AEP Stormwater Network Capacity
H.4.8.6	Design	5% AEP Stormwater Network Capacity
H.4.8.7	Design	5% AEP Stormwater Network Capacity
H.5.8.0	Design	2% AEP Stormwater Network Capacity
H.5.8.1	Design	2% AEP Stormwater Network Capacity
H.5.8.2	Design	2% AEP Stormwater Network Capacity
H.5.8.3	Design	2% AEP Stormwater Network Capacity
H.5.8.4	Design	2% AEP Stormwater Network Capacity
H.5.8.5	Design	2% AEP Stormwater Network Capacity
H.5.8.6	Design	2% AEP Stormwater Network Capacity
H.5.8.7	Design	2% AEP Stormwater Network Capacity

H.6.8.0	Design	1% AEP Stormwater Network Capacity
H.6.8.1	Design	1% AEP Stormwater Network Capacity
H.6.8.2	Design	1% AEP Stormwater Network Capacity
H.6.8.3	Design	1% AEP Stormwater Network Capacity
H.6.8.4	Design	1% AEP Stormwater Network Capacity
H.6.8.5	Design	1% AEP Stormwater Network Capacity
H.6.8.6	Design	1% AEP Stormwater Network Capacity
H.6.8.7	Design	1% AEP Stormwater Network Capacity
H.7.8.0	Design	0.5% AEP Stormwater Network Capacity
H.7.8.1	Design	0.5% AEP Stormwater Network Capacity
H.7.8.2	Design	0.5% AEP Stormwater Network Capacity
H.7.8.3	Design	0.5% AEP Stormwater Network Capacity
H.7.8.4	Design	0.5% AEP Stormwater Network Capacity
H.7.8.5	Design	0.5% AEP Stormwater Network Capacity
H.7.8.6	Design	0.5% AEP Stormwater Network Capacity
H.7.8.7	Design	0.5% AEP Stormwater Network Capacity
H.8.8.0	Design	0.2% AEP Stormwater Network Capacity
H.8.8.1	Design	0.2% AEP Stormwater Network Capacity
H.8.8.2	Design	0.2% AEP Stormwater Network Capacity
H.8.8.3	Design	0.2% AEP Stormwater Network Capacity
H.8.8.4	Design	0.2% AEP Stormwater Network Capacity
H.8.8.5	Design	0.2% AEP Stormwater Network Capacity
H.8.8.6	Design	0.2% AEP Stormwater Network Capacity
H.8.8.7	Design	0.2% AEP Stormwater Network Capacity
H.9.8.0	Design	PMF Stormwater Network Capacity
H.9.8.1	Design	PMF Stormwater Network Capacity
H.9.8.2	Design	PMF Stormwater Network Capacity
H.9.8.3	Design	PMF Stormwater Network Capacity
H.9.8.4	Design	PMF Stormwater Network Capacity
H.9.8.5	Design	PMF Stormwater Network Capacity
H.9.8.6	Design	PMF Stormwater Network Capacity
H.9.8.7	Design	PMF Stormwater Network Capacity

APPENDIX

I

COASTAL INTERACTION MAPS

Figure	Scenario	Title
I.0.0.0	Overall	Figure Inset Locations
I.1.1.0	Coastal Interaction - Catchment Flooding and Storm Surge	5% AEP Water Level Difference
I.1.1.1	Coastal Interaction - Catchment Flooding and Storm Surge	5% AEP Water Level Difference
I.1.1.2	Coastal Interaction - Catchment Flooding and Storm Surge	5% AEP Water Level Difference
I.1.1.3	Coastal Interaction - Catchment Flooding and Storm Surge	5% AEP Water Level Difference
I.1.1.4	Coastal Interaction - Catchment Flooding and Storm Surge	5% AEP Water Level Difference
I.1.1.5	Coastal Interaction - Catchment Flooding and Storm Surge	5% AEP Water Level Difference
I.1.1.6	Coastal Interaction - Catchment Flooding and Storm Surge	5% AEP Water Level Difference
I.1.1.7	Coastal Interaction - Catchment Flooding and Storm Surge	5% AEP Water Level Difference
I.2.1.0	Coastal Interaction - Catchment Flooding and Storm Surge	1% AEP Water Level Difference
I.2.1.1	Coastal Interaction - Catchment Flooding and Storm Surge	1% AEP Water Level Difference
I.2.1.2	Coastal Interaction - Catchment Flooding and Storm Surge	1% AEP Water Level Difference
I.2.1.3	Coastal Interaction - Catchment Flooding and Storm Surge	1% AEP Water Level Difference
I.2.1.4	Coastal Interaction - Catchment Flooding and Storm Surge	1% AEP Water Level Difference
I.2.1.5	Coastal Interaction - Catchment Flooding and Storm Surge	1% AEP Water Level Difference
I.2.1.6	Coastal Interaction - Catchment Flooding and Storm Surge	1% AEP Water Level Difference
I.2.1.7	Coastal Interaction - Catchment Flooding and Storm Surge	1% AEP Water Level Difference

APPENDIX

J

CLIMATE CHANGE MAPS

Figure	Scenario	Title
J.0.0.0	Overall	Figure Inset Locations
J.1.1.0	Climate Change - 2050 RCP 8.5	1% AEP Water Level Difference
J.1.1.1	Climate Change - 2050 RCP 8.5	1% AEP Water Level Difference
J.1.1.2	Climate Change - 2050 RCP 8.5	1% AEP Water Level Difference
J.1.1.3	Climate Change - 2050 RCP 8.5	1% AEP Water Level Difference
J.1.1.4	Climate Change - 2050 RCP 8.5	1% AEP Water Level Difference
J.1.1.5	Climate Change - 2050 RCP 8.5	1% AEP Water Level Difference
J.1.1.6	Climate Change - 2050 RCP 8.5	1% AEP Water Level Difference
J.1.1.7	Climate Change - 2050 RCP 8.5	1% AEP Water Level Difference
J.2.1.0	Climate Change - 2070 RCP 8.5	1% AEP Water Level Difference
J.2.1.1	Climate Change - 2070 RCP 8.5	1% AEP Water Level Difference
J.2.1.2	Climate Change - 2070 RCP 8.5	1% AEP Water Level Difference
J.2.1.3	Climate Change - 2070 RCP 8.5	1% AEP Water Level Difference
J.2.1.4	Climate Change - 2070 RCP 8.5	1% AEP Water Level Difference
J.2.1.5	Climate Change - 2070 RCP 8.5	1% AEP Water Level Difference
J.2.1.6	Climate Change - 2070 RCP 8.5	1% AEP Water Level Difference
J.2.1.7	Climate Change - 2070 RCP 8.5	1% AEP Water Level Difference
J.3.1.0	Climate Change - 2090 RCP 8.5	1% AEP Water Level Difference
J.3.1.1	Climate Change - 2090 RCP 8.5	1% AEP Water Level Difference
J.3.1.2	Climate Change - 2090 RCP 8.5	1% AEP Water Level Difference
J.3.1.3	Climate Change - 2090 RCP 8.5	1% AEP Water Level Difference
J.3.1.4	Climate Change - 2090 RCP 8.5	1% AEP Water Level Difference
J.3.1.5	Climate Change - 2090 RCP 8.5	1% AEP Water Level Difference
J.3.1.6	Climate Change - 2090 RCP 8.5	1% AEP Water Level Difference
J.3.1.7	Climate Change - 2090 RCP 8.5	1% AEP Water Level Difference
J.4.1.0	Climate Change - 2050 RCP 8.5	PMF Water Level Difference
J.4.1.1	Climate Change - 2050 RCP 8.5	PMF Water Level Difference
J.4.1.2	Climate Change - 2050 RCP 8.5	PMF Water Level Difference
J.4.1.3	Climate Change - 2050 RCP 8.5	PMF Water Level Difference
J.4.1.4	Climate Change - 2050 RCP 8.5	PMF Water Level Difference
J.4.1.5	Climate Change - 2050 RCP 8.5	PMF Water Level Difference
J.4.1.6	Climate Change - 2050 RCP 8.5	PMF Water Level Difference
J.4.1.7	Climate Change - 2050 RCP 8.5	PMF Water Level Difference
J.5.1.0	Climate Change - 2070 RCP 8.5	PMF Water Level Difference
J.5.1.1	Climate Change - 2070 RCP 8.5	PMF Water Level Difference
J.5.1.2	Climate Change - 2070 RCP 8.5	PMF Water Level Difference
J.5.1.3	Climate Change - 2070 RCP 8.5	PMF Water Level Difference
J.5.1.4	Climate Change - 2070 RCP 8.5	PMF Water Level Difference
J.5.1.5	Climate Change - 2070 RCP 8.5	PMF Water Level Difference
J.5.1.6	Climate Change - 2070 RCP 8.5	PMF Water Level Difference
J.5.1.7	Climate Change - 2070 RCP 8.5	PMF Water Level Difference

J.6.1.0	Climate Change - 2090 RCP 8.5	PMF Water Level Difference
J.6.1.1	Climate Change - 2090 RCP 8.5	PMF Water Level Difference
J.6.1.2	Climate Change - 2090 RCP 8.5	PMF Water Level Difference
J.6.1.3	Climate Change - 2090 RCP 8.5	PMF Water Level Difference
J.6.1.4	Climate Change - 2090 RCP 8.5	PMF Water Level Difference
J.6.1.5	Climate Change - 2090 RCP 8.5	PMF Water Level Difference
J.6.1.6	Climate Change - 2090 RCP 8.5	PMF Water Level Difference
J.6.1.7	Climate Change - 2090 RCP 8.5	PMF Water Level Difference

APPENDIX

K

SENSITIVITY ANALYSIS MAPS

Figure	Scenario	Title
K.0.0.0	Overall	Figure Inset Locations
K.1.1.0	Sensitivity - Building Representation	1% AEP Water Level Difference
K.1.1.1	Sensitivity - Building Representation	1% AEP Water Level Difference
K.1.1.2	Sensitivity - Building Representation	1% AEP Water Level Difference
K.1.1.3	Sensitivity - Building Representation	1% AEP Water Level Difference
K.1.1.4	Sensitivity - Building Representation	1% AEP Water Level Difference
K.1.1.5	Sensitivity - Building Representation	1% AEP Water Level Difference
K.1.1.6	Sensitivity - Building Representation	1% AEP Water Level Difference
K.1.1.7	Sensitivity - Building Representation	1% AEP Water Level Difference
K.2.1.0	Sensitivity - Blockage of Hydraulic Structures	1% AEP Water Level Difference
K.2.1.1	Sensitivity - Blockage of Hydraulic Structures	1% AEP Water Level Difference
K.2.1.2	Sensitivity - Blockage of Hydraulic Structures	1% AEP Water Level Difference
K.2.1.3	Sensitivity - Blockage of Hydraulic Structures	1% AEP Water Level Difference
K.2.1.4	Sensitivity - Blockage of Hydraulic Structures	1% AEP Water Level Difference
K.2.1.5	Sensitivity - Blockage of Hydraulic Structures	1% AEP Water Level Difference
K.2.1.6	Sensitivity - Blockage of Hydraulic Structures	1% AEP Water Level Difference
K.2.1.7	Sensitivity - Blockage of Hydraulic Structures	1% AEP Water Level Difference
K.3.1.0	Sensitivity - Loss Calibration	1% AEP Water Level Difference
K.3.1.1	Sensitivity - Loss Calibration	1% AEP Water Level Difference
K.3.1.2	Sensitivity - Loss Calibration	1% AEP Water Level Difference
K.3.1.3	Sensitivity - Loss Calibration	1% AEP Water Level Difference
K.3.1.4	Sensitivity - Loss Calibration	1% AEP Water Level Difference
K.3.1.5	Sensitivity - Loss Calibration	1% AEP Water Level Difference
K.3.1.6	Sensitivity - Loss Calibration	1% AEP Water Level Difference
K.3.1.7	Sensitivity - Loss Calibration	1% AEP Water Level Difference
K.4.1.0	Sensitivity - Roughness 20% Increase	1% AEP Water Level Difference
K.4.1.1	Sensitivity - Roughness 20% Increase	1% AEP Water Level Difference
K.4.1.2	Sensitivity - Roughness 20% Increase	1% AEP Water Level Difference
K.4.1.3	Sensitivity - Roughness 20% Increase	1% AEP Water Level Difference
K.4.1.4	Sensitivity - Roughness 20% Increase	1% AEP Water Level Difference
K.4.1.5	Sensitivity - Roughness 20% Increase	1% AEP Water Level Difference
K.4.1.6	Sensitivity - Roughness 20% Increase	1% AEP Water Level Difference
K.4.1.7	Sensitivity - Roughness 20% Increase	1% AEP Water Level Difference
K.5.1.0	Sensitivity - Roughness 20% Decrease	1% AEP Water Level Difference
K.5.1.1	Sensitivity - Roughness 20% Decrease	1% AEP Water Level Difference
K.5.1.2	Sensitivity - Roughness 20% Decrease	1% AEP Water Level Difference
K.5.1.3	Sensitivity - Roughness 20% Decrease	1% AEP Water Level Difference
K.5.1.4	Sensitivity - Roughness 20% Decrease	1% AEP Water Level Difference
K.5.1.5	Sensitivity - Roughness 20% Decrease	1% AEP Water Level Difference
K.5.1.6	Sensitivity - Roughness 20% Decrease	1% AEP Water Level Difference
K.5.1.7	Sensitivity - Roughness 20% Decrease	1% AEP Water Level Difference

K.6.1.0	Sensitivity - Building Representation	PMF Water Level Difference
K.6.1.1	Sensitivity - Building Representation	PMF Water Level Difference
K.6.1.2	Sensitivity - Building Representation	PMF Water Level Difference
K.6.1.3	Sensitivity - Building Representation	PMF Water Level Difference
K.6.1.4	Sensitivity - Building Representation	PMF Water Level Difference
K.6.1.5	Sensitivity - Building Representation	PMF Water Level Difference
K.6.1.6	Sensitivity - Building Representation	PMF Water Level Difference
K.6.1.7	Sensitivity - Building Representation	PMF Water Level Difference
K.7.1.0	Sensitivity - Blockage of Hydraulic Structures	PMF Water Level Difference
K.7.1.1	Sensitivity - Blockage of Hydraulic Structures	PMF Water Level Difference
K.7.1.2	Sensitivity - Blockage of Hydraulic Structures	PMF Water Level Difference
K.7.1.3	Sensitivity - Blockage of Hydraulic Structures	PMF Water Level Difference
K.7.1.4	Sensitivity - Blockage of Hydraulic Structures	PMF Water Level Difference
K.7.1.5	Sensitivity - Blockage of Hydraulic Structures	PMF Water Level Difference
K.7.1.6	Sensitivity - Blockage of Hydraulic Structures	PMF Water Level Difference
K.7.1.7	Sensitivity - Blockage of Hydraulic Structures	PMF Water Level Difference
K.8.1.0	Sensitivity - Loss Calibration	PMF Water Level Difference
K.8.1.1	Sensitivity - Loss Calibration	PMF Water Level Difference
K.8.1.2	Sensitivity - Loss Calibration	PMF Water Level Difference
K.8.1.3	Sensitivity - Loss Calibration	PMF Water Level Difference
K.8.1.4	Sensitivity - Loss Calibration	PMF Water Level Difference
K.8.1.5	Sensitivity - Loss Calibration	PMF Water Level Difference
K.8.1.6	Sensitivity - Loss Calibration	PMF Water Level Difference
K.8.1.7	Sensitivity - Loss Calibration	PMF Water Level Difference
K.9.1.0	Sensitivity - Roughness 20% Increase	PMF Water Level Difference
K.9.1.1	Sensitivity - Roughness 20% Increase	PMF Water Level Difference
K.9.1.2	Sensitivity - Roughness 20% Increase	PMF Water Level Difference
K.9.1.3	Sensitivity - Roughness 20% Increase	PMF Water Level Difference
K.9.1.4	Sensitivity - Roughness 20% Increase	PMF Water Level Difference
K.9.1.5	Sensitivity - Roughness 20% Increase	PMF Water Level Difference
K.9.1.6	Sensitivity - Roughness 20% Increase	PMF Water Level Difference
K.9.1.7	Sensitivity - Roughness 20% Increase	PMF Water Level Difference
K.10.1.0	Sensitivity - Roughness 20% Decrease	PMF Water Level Difference
K.10.1.1	Sensitivity - Roughness 20% Decrease	PMF Water Level Difference
K.10.1.2	Sensitivity - Roughness 20% Decrease	PMF Water Level Difference
K.10.1.3	Sensitivity - Roughness 20% Decrease	PMF Water Level Difference
K.10.1.4	Sensitivity - Roughness 20% Decrease	PMF Water Level Difference
K.10.1.5	Sensitivity - Roughness 20% Decrease	PMF Water Level Difference
K.10.1.6	Sensitivity - Roughness 20% Decrease	PMF Water Level Difference
K.10.1.7	Sensitivity - Roughness 20% Decrease	PMF Water Level Difference

APPENDIX

L

ARR 1987 COMPARISON MAPS

Figure	Scenario	Title
L.0.0.0	Overall	Figure Inset Locations
L.1.1.0	ARR 1987 Less ARR 2019	5% AEP Water Level Difference
L.1.1.1	ARR 1987 Less ARR 2019	5% AEP Water Level Difference
L.1.1.2	ARR 1987 Less ARR 2019	5% AEP Water Level Difference
L.1.1.3	ARR 1987 Less ARR 2019	5% AEP Water Level Difference
L.1.1.4	ARR 1987 Less ARR 2019	5% AEP Water Level Difference
L.1.1.5	ARR 1987 Less ARR 2019	5% AEP Water Level Difference
L.1.1.6	ARR 1987 Less ARR 2019	5% AEP Water Level Difference
L.1.1.7	ARR 1987 Less ARR 2019	5% AEP Water Level Difference
L.2.1.0	ARR 1987 Less ARR 2019	1% AEP Water Level Difference
L.2.1.1	ARR 1987 Less ARR 2019	1% AEP Water Level Difference
L.2.1.2	ARR 1987 Less ARR 2019	1% AEP Water Level Difference
L.2.1.3	ARR 1987 Less ARR 2019	1% AEP Water Level Difference
L.2.1.4	ARR 1987 Less ARR 2019	1% AEP Water Level Difference
L.2.1.5	ARR 1987 Less ARR 2019	1% AEP Water Level Difference
L.2.1.6	ARR 1987 Less ARR 2019	1% AEP Water Level Difference
L.2.1.7	ARR 1987 Less ARR 2019	1% AEP Water Level Difference

APPENDIX

M

LEVEE ASSESSMENT MAPS

Figure	Scenario	Title
M.0.0.0	Overall	Figure Inset Locations
M.1.1.0	Levee Assessment - Existing	20% AEP Water Level Difference
M.1.1.1	Levee Assessment - Existing	20% AEP Water Level Difference
M.1.1.2	Levee Assessment - Existing	20% AEP Water Level Difference
M.1.1.3	Levee Assessment - Existing	20% AEP Water Level Difference
M.1.1.4	Levee Assessment - Existing	20% AEP Water Level Difference
M.1.1.5	Levee Assessment - Existing	20% AEP Water Level Difference
M.1.1.6	Levee Assessment - Existing	20% AEP Water Level Difference
M.1.1.7	Levee Assessment - Existing	20% AEP Water Level Difference
M.2.1.0	Levee Assessment - 2050	20% AEP Water Level Difference
M.2.1.1	Levee Assessment - 2050	20% AEP Water Level Difference
M.2.1.2	Levee Assessment - 2050	20% AEP Water Level Difference
M.2.1.3	Levee Assessment - 2050	20% AEP Water Level Difference
M.2.1.4	Levee Assessment - 2050	20% AEP Water Level Difference
M.2.1.5	Levee Assessment - 2050	20% AEP Water Level Difference
M.2.1.6	Levee Assessment - 2050	20% AEP Water Level Difference
M.2.1.7	Levee Assessment - 2050	20% AEP Water Level Difference
M.3.1.0	Levee Assessment - 2090	20% AEP Water Level Difference
M.3.1.1	Levee Assessment - 2090	20% AEP Water Level Difference
M.3.1.2	Levee Assessment - 2090	20% AEP Water Level Difference
M.3.1.3	Levee Assessment - 2090	20% AEP Water Level Difference
M.3.1.4	Levee Assessment - 2090	20% AEP Water Level Difference
M.3.1.5	Levee Assessment - 2090	20% AEP Water Level Difference
M.3.1.6	Levee Assessment - 2090	20% AEP Water Level Difference
M.3.1.7	Levee Assessment - 2090	20% AEP Water Level Difference
M.4.1.0	Levee Assessment - Existing	1% AEP Water Level Difference
M.4.1.1	Levee Assessment - Existing	1% AEP Water Level Difference
M.4.1.2	Levee Assessment - Existing	1% AEP Water Level Difference
M.4.1.3	Levee Assessment - Existing	1% AEP Water Level Difference
M.4.1.4	Levee Assessment - Existing	1% AEP Water Level Difference
M.4.1.5	Levee Assessment - Existing	1% AEP Water Level Difference
M.4.1.6	Levee Assessment - Existing	1% AEP Water Level Difference
M.4.1.7	Levee Assessment - Existing	1% AEP Water Level Difference
M.5.1.0	Levee Assessment - 2050	1% AEP Water Level Difference
M.5.1.1	Levee Assessment - 2050	1% AEP Water Level Difference
M.5.1.2	Levee Assessment - 2050	1% AEP Water Level Difference
M.5.1.3	Levee Assessment - 2050	1% AEP Water Level Difference
M.5.1.4	Levee Assessment - 2050	1% AEP Water Level Difference
M.5.1.5	Levee Assessment - 2050	1% AEP Water Level Difference
M.5.1.6	Levee Assessment - 2050	1% AEP Water Level Difference
M.5.1.7	Levee Assessment - 2050	1% AEP Water Level Difference

M.6.1.0	Levee Assessment - 2090	1% AEP Water Level Difference
M.6.1.1	Levee Assessment - 2090	1% AEP Water Level Difference
M.6.1.2	Levee Assessment - 2090	1% AEP Water Level Difference
M.6.1.3	Levee Assessment - 2090	1% AEP Water Level Difference
M.6.1.4	Levee Assessment - 2090	1% AEP Water Level Difference
M.6.1.5	Levee Assessment - 2090	1% AEP Water Level Difference
M.6.1.6	Levee Assessment - 2090	1% AEP Water Level Difference
M.6.1.7	Levee Assessment - 2090	1% AEP Water Level Difference

APPENDIX

N

CONSEQUENCES OF FLOODING MAPS

Figure	Scenario	Title
N.0.0.0	Overall	Figure Inset Locations
N.1.1.0	Flood Planning Area	Extents
N.1.1.1	Flood Planning Area	Extents
N.1.1.2	Flood Planning Area	Extents
N.1.1.3	Flood Planning Area	Extents
N.1.1.4	Flood Planning Area	Extents
N.1.1.5	Flood Planning Area	Extents
N.1.1.6	Flood Planning Area	Extents
N.1.1.7	Flood Planning Area	Extents
N.1.2.0	Flood Planning Area	Freeboard Requirement
N.1.2.1	Flood Planning Area	Freeboard Requirement
N.1.2.2	Flood Planning Area	Freeboard Requirement
N.1.2.3	Flood Planning Area	Freeboard Requirement
N.1.2.4	Flood Planning Area	Freeboard Requirement
N.1.2.5	Flood Planning Area	Freeboard Requirement
N.1.2.6	Flood Planning Area	Freeboard Requirement
N.1.2.7	Flood Planning Area	Freeboard Requirement
N.2.1.0	Emergency Response	1% AEP Classification
N.2.1.1	Emergency Response	1% AEP Classification
N.2.1.2	Emergency Response	1% AEP Classification
N.2.1.3	Emergency Response	1% AEP Classification
N.2.1.4	Emergency Response	1% AEP Classification
N.2.1.5	Emergency Response	1% AEP Classification
N.2.1.6	Emergency Response	1% AEP Classification
N.2.1.7	Emergency Response	1% AEP Classification
N.2.2.0	Emergency Response	PMF Classification
N.2.2.1	Emergency Response	PMF Classification
N.2.2.2	Emergency Response	PMF Classification
N.2.2.3	Emergency Response	PMF Classification
N.2.2.4	Emergency Response	PMF Classification
N.2.2.5	Emergency Response	PMF Classification
N.2.2.6	Emergency Response	PMF Classification
N.2.2.7	Emergency Response	PMF Classification
N.3.1.0	Land Use	Flood Planning Constraint Categories
N.3.1.1	Land Use	Flood Planning Constraint Categories
N.3.1.2	Land Use	Flood Planning Constraint Categories
N.3.1.3	Land Use	Flood Planning Constraint Categories
N.3.1.4	Land Use	Flood Planning Constraint Categories
N.3.1.5	Land Use	Flood Planning Constraint Categories
N.3.1.6	Land Use	Flood Planning Constraint Categories
N.3.1.7	Land Use	Flood Planning Constraint Categories

About Cardno

Cardno is a professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

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